A MOBILE SOURCE EMISSION INVENTORY SYSTEM FOR LIGHT DUTY VEHICLES IN THE SOUTH COAST AIR BASIN

ARB-4-1236

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ABSTRACT

This report presents the development of a mobile source emission inventory system for light duty vehicles in the South Coast Air Basin.

The development of a mobile source emission inventory system for light duty vehicles consisted of compiling a vehicle and driving data base for the South Coast Air Basin (SCAB) and implementing a methodology to estimate emissions with the degree of spatial and temporal resolution necessary for the proposed usage of the system.

The procedure used in developing the inventory system consists of obtaining vehicle miles traveled (VMT) for particular locations (grid square, freeway segment, etc.) and time periods and combining them with an emission factor obtained from the emission model.

The computerized emissions model produces emissions estimates for the South Coast Air Basin with 10 km grid spatial resolution and one hour temporal resolution. The model structure is basically independent of the spatial and temporal resolution chosen. The methodology developed involves dividing the SCAB into regions exhibiting similar driving patterns and then combining traffic model data and actual traffic count data to construct the VMT data base. The derivation of emission factors considered road type, average speed, temperature, vehicle model year distribution and hot/cold vehicle operation mix.

The system was demonstrated for a 1975 mobile emissions inventory for light duty vehicles in the South Coast Air Basin.

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1.0 INTRODUCTION

At the present time, motor vehicles represent the major source of HC, CO, and NO_x pollutants within the South Coast Air Basin (SCAB). Although heavy duty vehicles, motorcycles and aircraft contribute, recent studies, References (1) and (2), show that light duty vehicles (LDV) account for approximately 85% of total reactive hydrocarbon emissions, 97% of total CO emissions and 62% of NO_x emissions in the SCAB.

Typically, emissions from motor vehicles tend to be a function of the percentage of time a vehicle is operated in each driving mode which, in turn, is dependent on the habits of the driver, the type of street on which the vehicle is operated, and the degree of traffic congestion. Other factors affecting vehicular emissions are the type of emission control device, the condition of the vehicle, its size and the distribution of vehicles in time and location throughout the study area.

To properly assess the impact of mobile source emissions on air quality requires the development of a comprehensive emission inventory system. The development of a mobile source emissions inventory represents an important planning tool inasmuch as it characterizes, in a systematic way, the basic sources of automotive pollution. Such an inventory provides information concerning source emissions and defines the location, magnitude, frequency, duration and relative contribution of these emissions. A comprehensive inventory can be used both to measure historical control performance and to forecast the impact of additional control strategies as well as determine current emission levels. This report presents the results of a study undertaken to develop a mobile source emission inventory system for light duty vehicles in the South Coast Air Basin.

The primary objective of this study was to investigate the various methodologies currently used for mobile source emission inventories and implement that methodology best suited for the SCAB. The system was then to be demonstrated for a 1975 light duty vehicle mobile source emission inventory.

The study consisted of the following tasks:

- Characterization of light duty vehicle (passenger cars and light duty trucks) population and driving patterns in SCAB.
- Emission estimation techniques.
- Software development and implementation.

Following a presentation of the study's summary and conclusions in Section 2.0, the above tasks are discussed in detail in Section 3.0. The numerical results, including a 1975 mobile source emission inventory for light duty vehicles, are presented in Section 4.0.

2.0 SUMMARY AND CONCLUSIONS

The development of a mobile source emission inventory system for light duty vehicles consisted of compiling a vehicle and driving data base for the South Coast Air Basin (SCAB) and implementing a methodology to estimate emissions with the degree of spatial and temporal resolution necessary for the proposed usage of the system.

The procedure used in developing the inventory system consists of obtaining vehicle miles traveled for particular locations (grid square, freeway segment, etc.) and time periods from the data base and combining them with an emission factor obtained from the emission model. The emission factor is a quantitative estimate of the rate at which the pollutant is released to the atmosphere per vehicle mile traveled.

The data base consists of the following information:

- Distribution of vehicle population and annual vehicle miles traveled (VMT) by model year for the SCAB.
- Coordinates of all freeway, arterial and collector road segments in the SCAB.
- Traffic model estimates of annual average daily volume and average peak and off-peak speed on each road segment.
- Disaggregating factors based on actual traffic count data to provide weekend/weekday, seasonal, road type and hourly volume distribution.

The emissions model incorporates the methodology employed in Reference (3) with speed correction factors derived from chase car data developed during this study.

The computerized emissions model produces emissions estimates for the South Coast Air Basin with 10 km grid spatial resolution and one hour temporal resolution. The model structure is basically independent of the spatial and temporal resolution chosen. The associated data base, however, dictates the resolution of the system. The methodology developed involves dividing the SCAB into regions exhibiting similar driving patterns and then combining traffic model data and actual traffic count data to construct the data base. In order to obtain the desired spatial and temporal resolution in the model, the VMT data base was required to provide seasonal and hourly traffic volumes for each road type for both weekday and weekend conditions. VMT is determined on a link-by-link basis. An emission factor is obtained from the emissions model for the conditions on each road link. Factors considered in the derivation of each emission factor are road type, average speed, temperature, vehicle model year distribution and hot/cold vehicle operation mix. Output of the model is very flexible, providing both tabular and graphical results.

The methodology developed during this research effort provides the California Air Resources Board with a flexible and efficient tool capable of evaluating a wide range of vehicle emission control alternatives and other dynamic conditions (e.g., retrofit programs, fuel scarcity, change in vehicle control systems, population and vehicle mix modifications and road configurations). In addition, a number of possible areas for improvement in the methodology have been identified, primarily in emission factor generation. Continued research in this area could further improve mobile source emission estimations.

Presented below is a summary of the results of the 1975 emissions inventory for the South Coast Air Basin. The detailed inventory is presented in Section 4.0.

Summary of 1975 Emissions	Light Duty Passenger Cars	Light Duty Trucks	Total
Number of Vehicles	4,829,500	755,600	5,585,100
Average Daily VMT	1.26×10^8	2.18×10^7	1.48×10^8
Annual Average Daily Exhuast Hydrocarbons Emissions (Tons)	514	87	601
Annual Average Daily Carbon Monoxide Emissions (Tons)	5141	858	5999
Annual Average Daily Nitrogen Oxides Emissions (Tons)	634	106	740
Annual Average Daily Sulfur Dioxide Emissions (Tons)	18.0	3.1	21.1
Annual Average Daily Particulates Emissions (Tons)	73.2	12.7	85.9
Annual Average Daily Evaporation Hydrocarbons Emissions (Tons)	391	61	452
Annual Average Daily Crankcase Hydrocarbons Emissions (Tons)	11.5	4.2	15.7

3.0 METHODOLOGY

The primary objective of this study was to investigate the various methodologies currently used for LDV mobile source emission inventories and implement that methodology best suited for the SCAB. This section will present a discussion of the various tasks undertaken to meet the study objectives.

Data Base Development Methodology

Since it is the distribution of VMT (vehicle miles traveled) that describes the temporal and geographical distribution of vehicular emissions, the ultimate resolution and accuracy of the inventory can be no better than the resolution and accuracy of the VMT data on which it is based. In most previous inventories the degree of resolution has been limited to county-wide or basin-wide average annual daily emissions estimates. (Average annual daily emissions are the annual emissions divided by 365.) This study required hourly emissions estimates that reflected seasonal and day-of-week variations. It was, therefore, necessary to develop a new methodology which would provide this degree of resolution.

Two basic approaches could have been employed in developing such an inventory. The first consists of obtaining traffic volume, average speed, and other related data, and then developing a computer model with the necessary characteristics. The second approach consists of modifying and expanding an existing transportation simulation model.

The first approach, which may be referred to as a "raw data" method, has several advantages. First, since the model would be designed specifically for generating emissions estimates, it would have the correct emphasis. Transportation simulation models are designed primarily to aid in the selection of new freeway and surface street routes and support other types of transporation oriented studies. As such, they tend not to have some of the features necessary for emission inventory purposes. For example, although hourly, day-of-week, and seasonal variations in emissions are required, transportation models typically provide only annual average daily traffic (AADT) volume estimates. By developing a model specifically for emissions inventory work, these requirements could be met. Second, the required degree of temporal and geographical resolution would be maintained. By using the raw data directly, the information could be aggregated in a manner allowing it to be processed effectively without losing the necessary detail. As practical considerations normally require that raw data be aggregated in some manner, this approach would allow the aggregation to be done in the most appropriate fashion. Third, the model could be developed so that the resulting emission estimates are stratified in the most useful way (i.e., for control strategy development).

The major disadvantage of this approach is that, because of the nature of the data which is required, assembling the data base would be an expensive and time consuming process. The required data, primarily traffic counts, are gathered by several state, county and municipal traffic agencies with overlapping jurisdictions. Thus, for any given locale, traffic data are frequently spread out among three agencies. Furthermore, as a rule the data are not readily available on computer tape or punch cards, nor are they recorded in any standard format. The greatest difficulty, however, is that the data tend to be incomplete and inaccurate.

There are, therefore, two primary reasons that the raw data approach is not feasible. First, it is not technically feasible because of the lack of complete and accurate traffic data. It is probably not possible to assemble a sufficient amount of information to adequately characterize traffic flow patterns in the Basin. Second, because the required data are not computerized and are on file with several governmental agencies, the time required to collect and process the data would be prohibitive.

The alternate approach is one based on a transportation simulation model. Although the details may vary, all such models are similar to the one developed for the Los Angeles area. Developed by the Los Angeles Regional Transportation Study (LARTS), it is a link-oriented attraction model. LARTS consists of a detailed computerized simulation of the system of freeways and major surface streets in the Los Angeles area and estimates the traffic volume (AADT) and average speed on each roadway segment.

The roadway network consists of a series of roadway segments called links. Figure 1 illustrates a small portion of the network. Each of the approximately 9600 links, which range in length from about 0.1 miles to 8.0 miles, is defined by a set of two coordinates which specify its end points or nodes. The LARTS model uses a "map-inch" coordinate system with an arbitrarily selected origin. This coordinate system was transformed to the UTM (Universal Transverse Mercator) system, which is the standard system for emissions inventories (see Figure 2). The transformation was made by selecting a series of easily identifiable locations in various parts of the Basin, determining their coordinates in each system, and then developing the necessary transformation equations. The rotational term is omitted since it has been determined that it is negligible.

The equations are:

$$X_{UTM} = (6.02 \times 10^{-3})\ (X_{mi}) + (2.10 \times 10^{2})$$

$$Y_{UTM} = (6.14 \times 10^{-3})\ (Y_{mi}) + (3.39 \times 10^{3})$$

where:

X_{UTM} = UTM based X-coordinate

Y_{UTM} = UTM based Y-coordinate

X_{mi} = LARTS map-inch based X-coordinate

Y_{mi} = LARTS map-inch based Y-coordinate

Traffic was allocated to the road network on the basis of a detailed origin-destination survey. The survey consisted of both household interviews with 30,800 households and cordon interviews at 18 heavily traveled locations in the Basin. The household interviews were designed to gather detailed information on where, when, and for what reasons residents of the Basin travel by car or truck. The cordon interviews were used primarily to determine the driving habits of non-residents and to serve as a cross-check on certain information obtained during the household interviews. The survey data were then used to estimate traffic flow patterns within and between 1236 major traffic analysis zones. The patterns were presented in terms of annual average daily traffic (AADT) estimates. Since the network does not contain every street in the Basin,

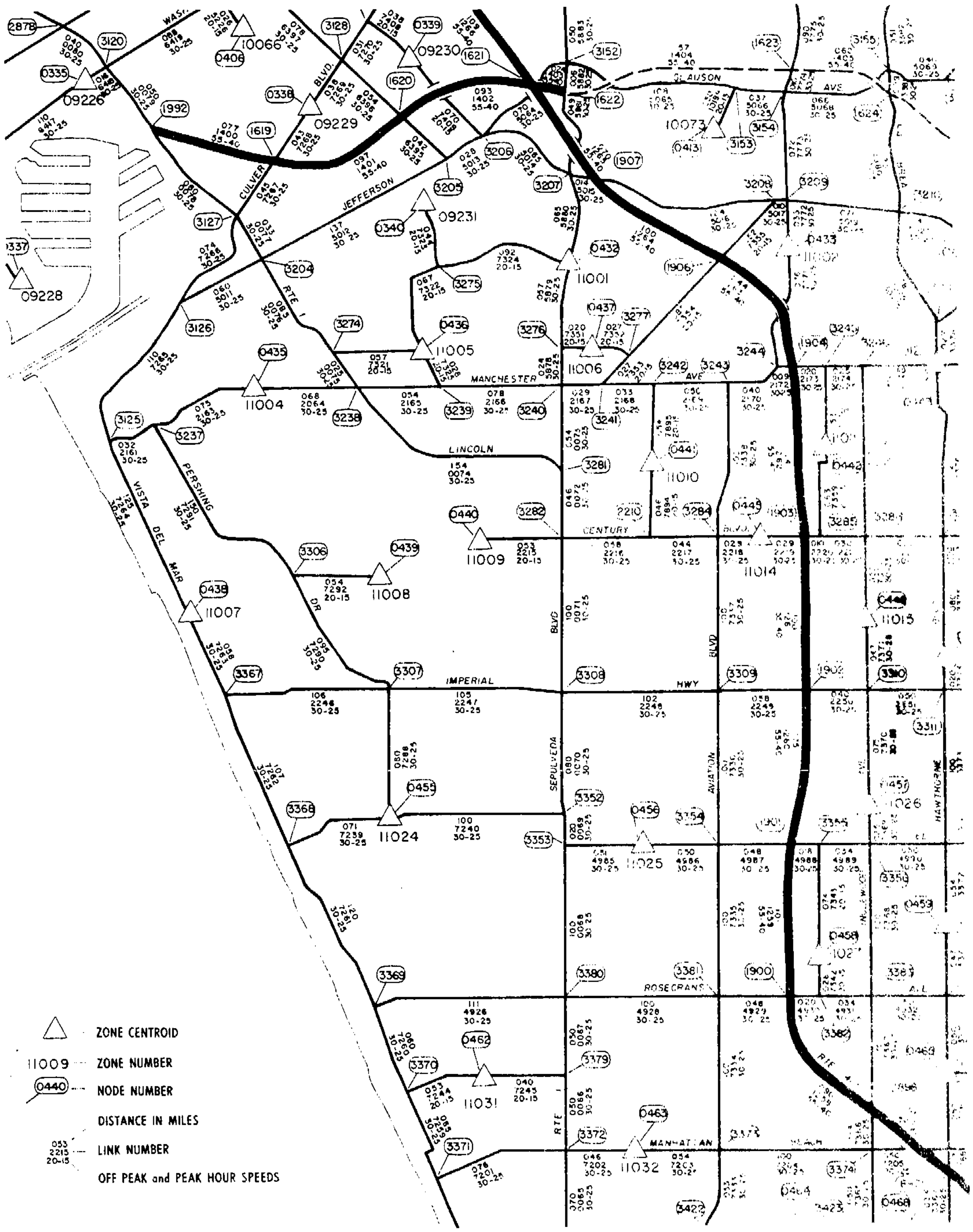


Figure 1. LARTS Roadway Network

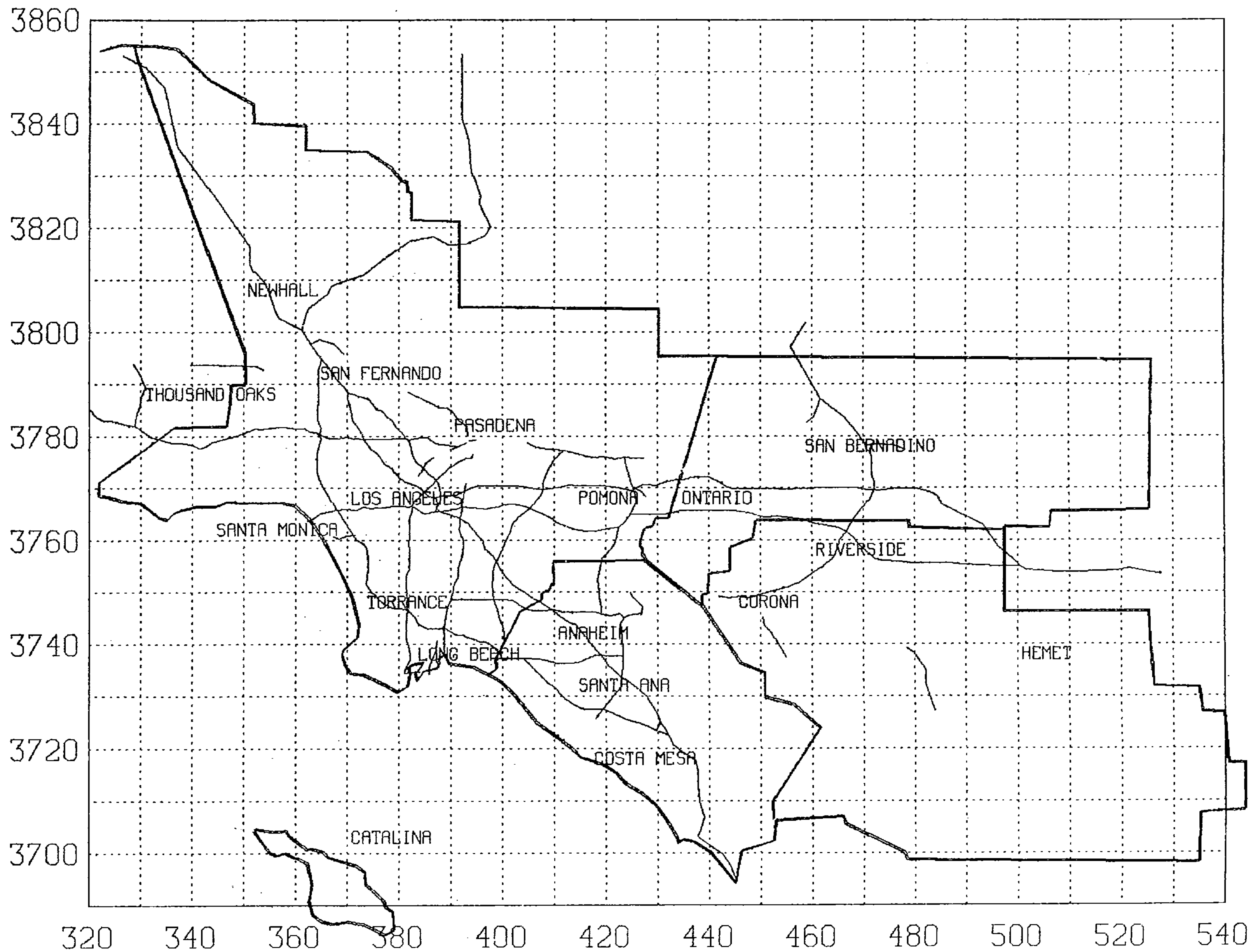


Figure 2. UTM Map of the SCAB

traffic that actually flows on the streets not included in the LARTS network is assigned to roads that are in the network. That is, a link representing a major surface street is assigned all of the traffic that actually flows on it, plus the traffic that flows on the smaller streets adjacent to it. This is illustrated in Figure 3.

Each link also has associated with it two average link speeds, one which corresponds to peak hour traffic conditions and one which corresponds to off-peak hour conditions.

A careful distinction must be made between the term average link speed and the term average speed as it is generally used. In the LARTS sense, average link speed means the time required to traverse the link divided by its length. The travel time includes stops for stop signs, traffic signals and traffic congestion. The average link speed does <u>not</u> correspond to the mean speed of a sample of cars passing by a given point on the link. Throughout this report, average speed should be taken to mean the speed over a road segment including stops.

It should be noted that the average link speeds in LARTS are "policy speeds". That is, for each of several areas in the Basin, a set of two speeds (peak and off-peak freeway or peak and off-peak non-freeway) was assigned to each link in that area. Figure 4 shows which speeds were originally assigned to each area. For 1975, all 60 mph speeds were arbitrarily reduced to 55 mph to reflect the change in the maximum highway speed.

Detailed descriptions of the LARTS model, the procedures used to develop it, and its limitations can be found in Reference (4).

A transportation model has several features which make it useful as a basis for an emissions inventory model. First, the computerized roadway network can provide a high degree of geographical resolution of traffic related emissions. The daily traffic estimates (AADT) for each link provide a starting point for defining how the emissions are distributed among each segment of road. Since these data are computerized, the network and daily traffic estimates can be used directly as a basis for the emissions model.

The transportation model does, however, have several major deficiencies. First, only weekday AADT estimates are provided while hourly, seasonal and day-of-week variations are required. The nature of the transportation model

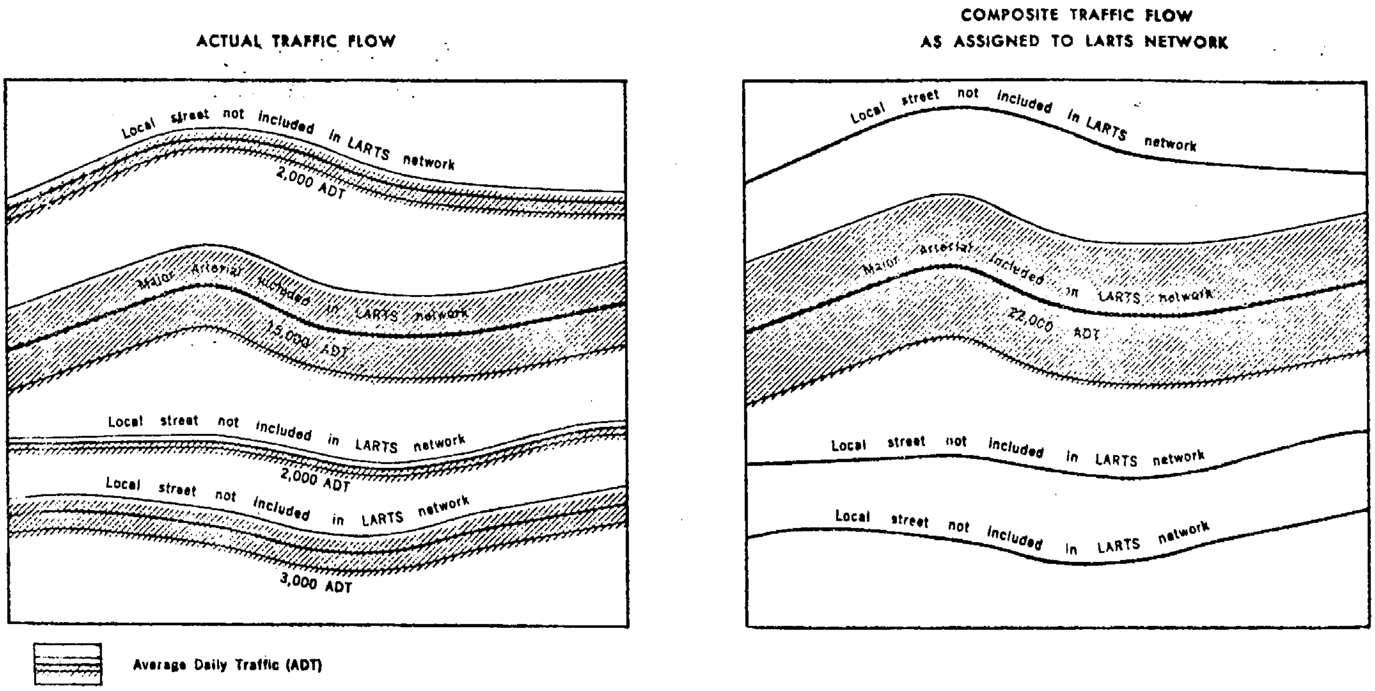


Figure 3. Actual and Composite Traffic Flow

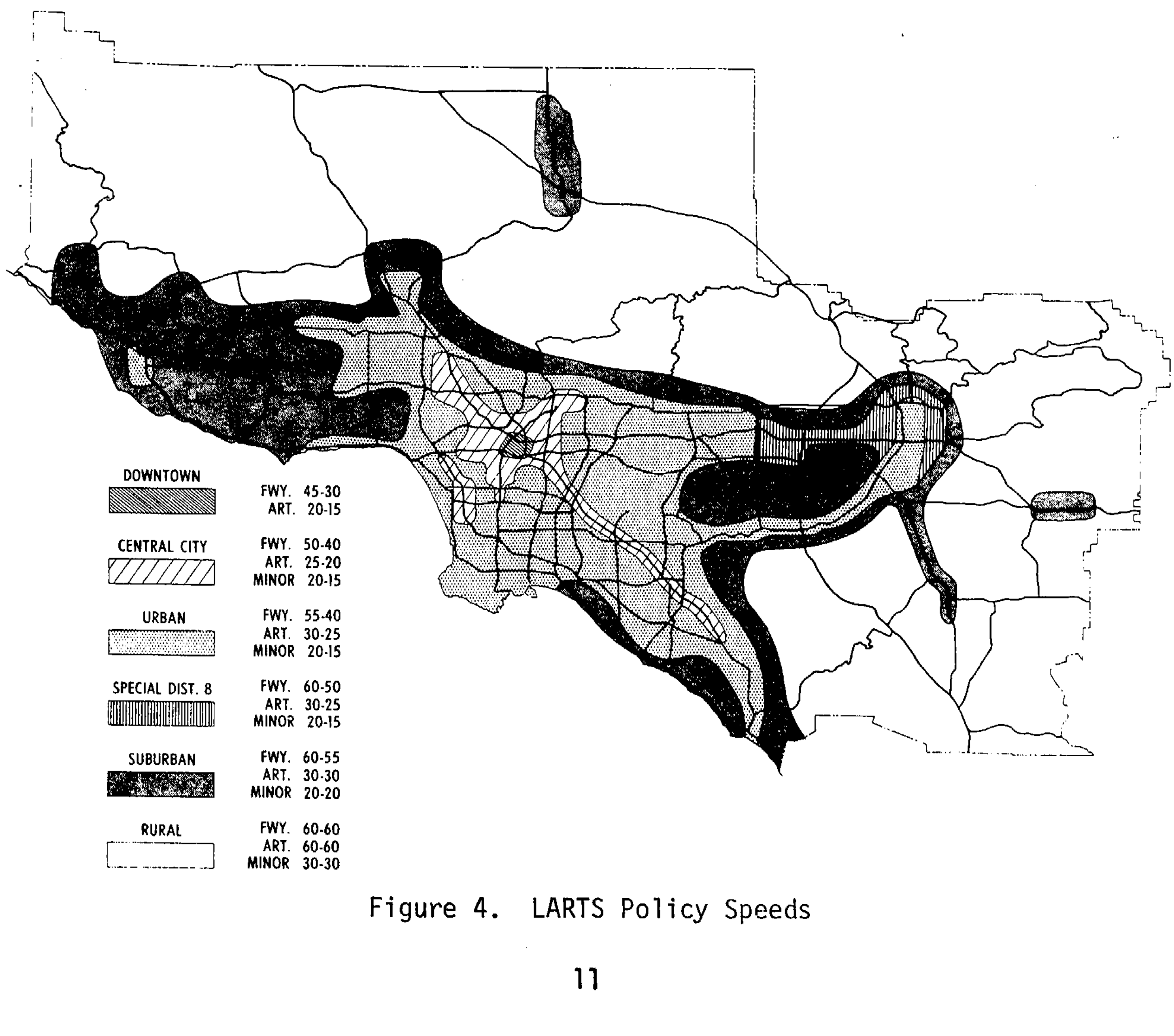


Figure 4. LARTS Policy Speeds

methodology makes anything less than daily volumes unreasonable. Second, AADT can be shown to be inaccurate in many cases by comparison with actual traffic count data. Again, the modeling techniques are not intended to provide accurate link-by-link volumes, but volumes that are considered adequate on a regional scale. As shown in Table 1, errors are random rather than systematic and tend to cancel each other if several links close together are compared.

Disaggregation of LARTS Model Data

Since it was determined that the LARTS transportation model would be used as the basis for the emissions inventory for the South Coast Air Basin, it was necessary to develop procedures for further disaggregating the traffic volumes it predicted. The methodology developed consisted of the following steps:

- Hourly traffic volume counts for one week in each calendar quarter were obtained for locations in a representative number of grid squares.
- For each grid square and calendar quarter, a line graph showing diurnal variations in traffic volume for an average of the five weekdays and another for the two weekend days were prepared.
- The graphs for freeways and for surface streets in each grid square were compared to the corresponding graphs for each of the other grid squares. Those with similar diurnal traffic patterns were identified and used to define a series of traffic pattern types.
- Those grid squares with both similar freeway traffic pattern types and surface street traffic pattern types were considered to constitute a grid square type.
- A series of disaggregating factors were developed for each grid square type which, when applied to the AADT for each link in the roadway network, provided hourly estimates of traffic volume on a day-of-week and seasonal basis.

To assure that seasonal traffic variations were taken into account, hourly counts for seven consecutive days in each calendar quarter were required. Whenever possible, counts in the middle month of each quarter

Table 1. Comparison of LARTS Estimated and Actual AADT

Freeway	Street	LARTS AADT Estimate	Actual Volume
Harbor Freeway	Between Vernon Ave. and Santa Barbara Ave.	183,000	199,000
	Between 8th/9th Streets and 5th/6th Streets	226,000	209,000
Pomona Freeway	Between Jct. Route 10 and Jct. Route 5	188,000	121,000
	Between Lorena St. and Indiana St.	146,000	123,000
Santa Monica - San Bernardino Freeways	Between Hoover St. and Harbor Freeway	242,000	217,000
	Between Los Angeles St. and San Pedro Avenue	181,000	188,000
	Between Soto St. and City Terrace Drive	136,000	151,000
San Bernardino Freeway	Between Eastern Ave. and Long Beach Freeway	130,000	138,000
	Between Long Beach Freeway and Fremont Exchanges	137,000	144,000
Long Beach Freeway	Between Washington Blvd. and Jct. Route 5	103,000	108,000
	Between Jct. Route 5 and Route 72	93,000	88,000
Santa Ana Freeway	Between Atlantic Blvd. and Jct. Route 7	224,000	146,000
	Between Garfield Ave. and Washington Blvd.	238,000	139,000
Ventura Freeway	Between Victory Blvd. and Jct. Route 5	67,000	90,000
	Between Concord Ave. and Pacific Ave.	89,000	89,000
	Between Glendale Blvd. and Route 2	74,000	62,000
Total AADT for all locations		2,457,000	2,212,000

were selected. Counts conducted on or near holidays were not used in order to avoid including abnormal traffic patterns. As shown below, the middle months are February, March, August and November. Notice that the winter, spring, summer and fall quarter do not exactly coincide with the winter, spring, summer and fall seasons.

Winter	Spring	Summer	Fall
January February March	April May June	July August September	October November December

Several different types of traffic counts are conducted by various traffic agencies. The most sophisticated and detailed were conducted by CalTrans (The California Department of Transportation) on what is known as the 42-Loop. On this portion of the freeway system, shown in Figure 5, traffic is counted continuously. The counts are processed by computer and printouts are available for every day of the year (except when counter or computer malfunctions occur). The least detailed counts are those that are conducted on a random basis, for one to three days, by county and local agencies. These counts are done only for special purposes. Between these extremes are several types of counts.

Table 2 shows the types of counts conducted by and available from CALTRANS and the four counties totally or partially in the South Coast Air Basin. Table 3 presents samples of some of the types of data that were used. Note that in several cases, the required seven consecutive days data in each quarter are not available.

In those cases where scheduled counts should have provided the necessary data, frequently they were either missing because of equipment malfunctions or errors in record keeping. For example, a frequent error which occurred showed the weekday morning traffic peak (rush hour) occurring between, say, 2:00 and 3:00 in the morning. In such cases, there is no way to recover the data.

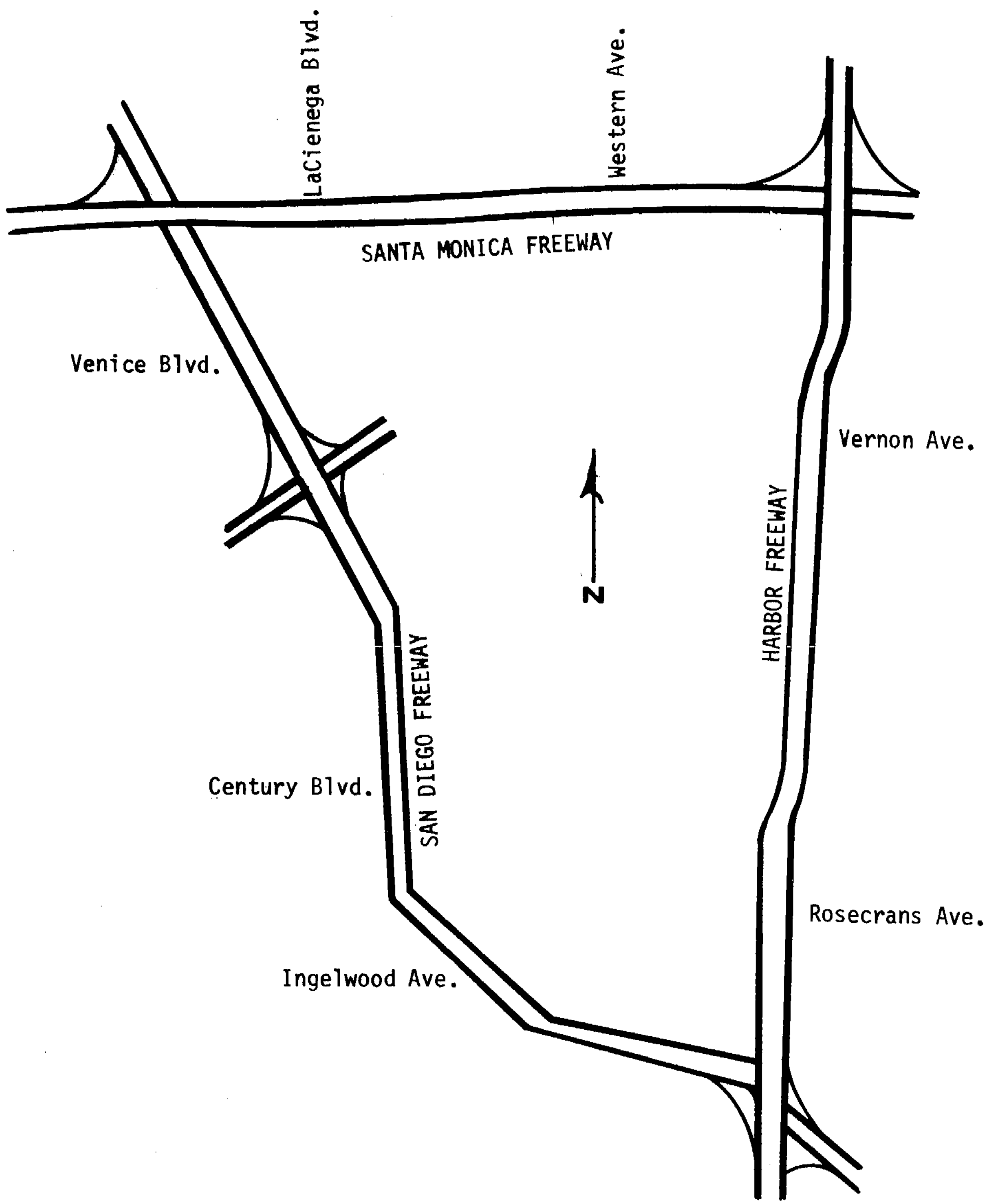


Figure 5. 42-Mile Loop

Table 2. Major Sources of Traffic Volume Information

Agency	Extent of Data Collection	Types of Data Collected
State Agency:		
CalTrans (California Department of Transportation)	Freeway Surveillance Project (42-mi. loop)	Continuous 5-minute and hourly traffic volumes and approximate average speed.
	Trend counts	Continuous hourly volumes at stations located on the entire freeway system in the basin.
	Monthly counts	Monthly counts of 1 week to 1 month duration; hourly volumes
	Quarterly counts	Hourly volumes for the same week each quarter
County Agencies:		
Los Angeles County Road Department	Continuous counts	Hourly volumes for 1 week most months (files incomplete)
	Other counts	Hourly volumes for 1-3 days at misc. locations
Orange County Road Department	Annual counts	Hourly volumes for several consecutive days in August only
	Other counts	Miscellaneous one day counts at numerous locations
San Bernardino County Road Dept.	Master counts	Several single day counts per year at numerous locations
	Other counts	Similar to master counts except counts done on a 3 to 4 year rotating schedule

Table 2. Major Sources of Traffic Volume Information (Continued)

Agency	Extent of Data Collection	Types of Data Collected
Riverside County Road Department	-----	No data available until after September 1976

Table 3. Sample Traffic Count Data

RT 5003-00 03.00 C O U N T Y OF V E N T U R A R O A D D E P T.

TRAFFIC VOLUME STUDY -- MACHINE, 15 MIN

STARTING TIME 02/25/75 TUE 12.00 AM
WEATHER------ CLEAR
CONDITIONS--- DRY
COUNT LOC---- 2500
DOCUMENT NU-- 00651
TYPE COUNT--- MASTER CT

LOCATION....148000 VICTORIA AVENUE NORTH OF 140900 TELEPHONE ROAD

START TIME	--- B O T H -00-	-15-	-30-	-45-	TOT.	%	ACC %	-00-	-15-	-30-	-45-	TOT.	%	ACC %	T O T A L S -00-	-15-	-30-	-45-	TOT.	%	ACC %	START TIME
12.00 AM	64	59	52	34	209	.93	.93						.00	.00	64	59	52	34	209	.93	.93	12.00 AM
01.00	28	32	17	12	89	.40	1.33						.00	.00	28	32	17	12	89	.40	1.33	01.00
02.00	17	17	14	12	60	.27	1.60						.00	.00	17	17	14	12	60	.27	1.60	02.00
03.00	12	7	6	4	29	.13	1.73						.00	.00	12	7	6	4	29	.13	1.73	03.00
04.00	9	10	1	4	24	.11	1.84						.00	.00	9	10	1	4	24	.11	1.84	04.00
05.00	69	48	92	167	376	1.68	3.52						.00	.00	69	48	92	167	376	1.68	3.52	05.00
06.00	163	237	365	544	1309	5.85	9.37						.00	.00	163	237	365	544	1309	5.85	9.37	06.00
07.00	337	314	317	334	1302	5.82	15.19						.00	.00	337	314	317	334	1302	5.82	15.19	07.00
08.00	297	237	202	270	1006	4.50	19.69						.00	.00	297	237	202	270	1006	4.50	19.69	08.00
09.00	285	232	232	304	1053	4.71	24.40						.00	.00	285	232	232	304	1053	4.71	24.40	09.00
10.00	368	311	324	370	1373	6.14	30.54						.00	.00	368	311	324	370	1373	6.14	30.54	10.00
11.00	474	462	383	406	1725	7.71	38.25						.00	.00	474	462	383	406	1725	7.71	38.25	11.00
12.00 PM	371	455	337	343	1506	6.73	44.98						.00	.00	371	455	337	343	1506	6.73	44.98	12.00 PM
01.00	338	439	400	408	1585	7.08	52.06						.00	.00	338	439	400	408	1585	7.08	52.06	01.00
02.00	343	408	428	412	1591	7.11	59.17						.00	.00	343	408	428	412	1591	7.11	59.17	02.00
03.00	399	393	436	440	1668	7.46	66.63						.00	.00	399	393	436	440	1668	7.46	66.63	03.00
04.00	451	528	459	442	1880	8.40	75.03						.00	.00	451	528	459	442	1880	8.40	75.03	04.00
05.00	393	335	300	287	1315	5.88	80.91						.00	.00	393	335	300	287	1315	5.88	80.91	05.00
06.00	332	306	291	291	1220	5.45	86.36						.00	.00	332	306	291	291	1220	5.45	86.36	06.00
07.00	268	239	259	192	958	4.28	90.64						.00	.00	268	239	259	192	958	4.28	90.64	07.00
08.00	167	196	194	149	706	3.16	93.80						.00	.00	167	196	194	149	706	3.16	93.80	08.00
09.00	145	113	109	114	481	2.15	95.95						.00	.00	145	113	109	114	481	2.15	95.95	09.00
10.00	118	112	94	119	443	1.98	97.93						.00	.00	118	112	94	119	443	1.98	97.93	10.00
11.00	190	113	82	80	465	2.08	100.01						.00	.00	190	113	82	80	465	2.08	100.01	11.00
TOTAL**					22373		100.01%							.00%					22373		100.01%	
% TO TOTAL							100.00%							.00%							100.00%	

A.M. PEAK BEGAN 11.00AM VOL. 1725 BEGAN 11.00AM VOL. 1725
P.M. PEAK BEGAN 04.00PM VOL. 1880 BEGAN 04.00PM VOL. 1880

AVERAGE 8 HIGHEST HOURS 1580 1580

Table 3. Sample Traffic Count Data (Continued)

LOS ANGELES COUNTY ROAD DEPARTMENT
PROGRAM - R6922

MACHINE TRAFFIC COUNT
PCS

DATE PROCESSED - C?-C?-75
REPORT NO. R6922.C1

LOCATION
SEPULVEDA BV W/O VERMONT AV

COUNT DATE
01/20/75

DAY COUNT BEGAN
MONDAY

COUNT TYPE
DIRECTIONAL

ABNORMAL CONDITION

ROAD TYPE
MAJOR

ZONE
89

R.D./CITY
CAR

DIRECTION	24 HOUR VOLUME	AM PEAK HOUR BEGAN	AM PEAK HOUR VOLUME	PM PEAK HOUR BEGAN	PM PEAK HOUR VOLUME	8TH HIGHEST HOUR
TOTAL	32,016	7:15	2,955	4:45	2,867	1,817
EAST-BD	15,509	7:15	1,826	3:15	1,194	880
WEST-BD	16,507	7:15	1,129	4:45	1,702	937

STREET CODES
32230 W/O 36070

REDUCTION NUMBER
634

PERIOD BEGAN	AM NORTH-BD EAST-BD 15'	AM NORTH-BD EAST-BD HOUR	AM SOUTH-BD WEST-BD 15'	AM SOUTH-BD WEST-BD HOUR	AM TOTAL 15'	AM TOTAL HOUR	PM NORTH-BD EAST-BD 15'	PM NORTH-BD EAST-BD HOUR	PM SOUTH-BD WEST-BD 15'	PM SOUTH-BD WEST-BD HOUR	PM TOTAL 15'	PM TOTAL HOUR
12:00	27	118	58	174	85	292	206	880	257	937	463	1317
12:15	33	109	44	144	77	253	215	884	216	870	431	1754
12:30	30	81	43	111	73	192	250	865	246	869	496	1734
12:45	28	61	29	92	57	153	209	824	218	870	427	1594
1:00	18	44	28	80	46	124	210	816	190	889	400	1705
1:15	5	35	11	60	16	95	196	810	215	910	411	1720
1:30	10	36	24	72	34	108	209	869	247	944	456	1813
1:45	11	41	17	64	28	105	201	920	237	956	438	1876
2:00	9	37	8	54	17	91	204	963	211	982	415	1945
2:15	6	37	23	52	29	89	255	1045	249	1059	504	2114
2:30	15	35	16	36	31	71	260	1102	259	1136	519	2238
2:45	7	31	7	30	14	61	244	1163	263	1215	507	2378
3:00	9	33	6	37	15	70	286	1189	299	1419	534	2608
3:15	4	30	7	36	11	66	312	1194	316	1467	628	2661
3:30	11	36	10	40	21	76	321	1151	338	1534	659	2685
3:45	9	45	14	40	23	85	270	1130	467	1601	737	2731
4:00	6	52	5	39	11	91	291	1119	346	1537	637	2656
4:15	10	73	11	41	21	114	269	1179	383	1537	652	2716
4:30	20	112	10	60	30	172	300	1176	405	1690	705	2866
4:45	16	154	13	112	29	266	259	1165	403	1702	662	2867
5:00	27	1214	7	201	34	415	351	1126	396	1698	747	2824
5:15	49	324	30	245	79	569	266	1014	486	1648	752	2662
5:30	62	491	62	324	124	805	289	924	417	1498	706	2422
5:45	76	688	102	462	178	1150	220	804	399	1337	619	2141
6:00	137	926	51	596	188	1522	239	750	346	1230	585	1930
6:15	206	1166	109	713	315	1879	176	704	336	1089	512	1793
6:30	269	1391	200	846	469	2237	169	662	306	935	475	1597
6:45	314	1574	236	962	550	2536	166	640	242	821	408	1461
7:00	377	1769	168	1029	545	2798	193	585	205	726	398	1311
7:15	431	1826	242	1129	673	2955	134	498	182	673	316	1171
7:30	452	1782	316	1107	768	2889	147	475	192	615	339	1090
7:45	509	1657	303	1009	812	2666	111	418	147	534	258	952
8:00	434	1402	268	939	702	2341	106	408	152	517	258	925
8:15	387	1220	220	846	607	2066	111	446	124	492	235	938
8:30	327	1063	218	810	545	1873	90	451	111	456	201	917
8:45	254	921	233	772	487	1693	101	448	130	454	231	902
9:00	252	835	175	728	427	1563	144	435	127	432	271	867
9:15	230	757	184	728	414	1485	116	367	98	415	214	732
9:30	185	693	180	748	365	1441	87	305	99	401	186	706
9:45	168	617	189	771	357	1398	88	259	108	375	196	634
10:00	174	542	175	805	349	1347	76	211	110	353	186	564
10:15	166	556	204	836	370	1392	54	198	84	293	138	491
10:30	109	621	203	847	312	1468	41	183	73	272	114	455
10:45	93	732	223	872	316	1604	40	214	86	255	126	469
11:00	188	835	206	893	394	1728	63	220	50	212	113	432
11:15	231	853	215	944	446	1797	39	184	63	220	102	404
11:30	220	837	228	945	448	1782	72	178	56	201	128	379
11:45	196	867	244	963	440	1830	46	136	43	188	89	324

Table 3. Sample Traffic Count Data (Continued)

TRF160 07/17/75 08:56

CALTRANS - TRAFFIC VOLUMES
DETAIL TRAFFIC COUNTS
PRELIMINARY ADT, PEAK HOUR %

DIST 07
CO ORA
RTE 1

CNTR STA 003
DIREC N
TYPE CC____

CT INTR 60 MIN.
CT FACT 0.50

USER ID __
BATCH __
PTID 3342

PAGE 1
TRAN=52

C = COMPUTER ESTIMATED COUNT
( ) = PARTIAL DAY TOTAL

POSTMILE-LEG 17.430 -B

NEWPORT BEACH, JAMBOREE RD

DATE	DAY		12-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	DAILY TOTAL	PK HR % PRE ADT
06-03-75	TUE	AM														
		PM			2440	1855	1750	1785	1240	1035	940	725	705	390	(12,865)	10.8
06-04-75	WED	AM	240	125	80	30	15	80	265	850	1115	1105	1295	1555	21,740	7.6
		PM	1535	1510	1690	1675	1600	1710	1235	1075	940	815	685	515		
06-05-75	THU	AM	240	180	80	35	25	70	250	855	1155	1055	1305	1545	22,065	8.0
		PM	1655	1535	1560	1580	1690	1815	1280	1040	970	910	735	500		
06-06-75	FRI	AM	280	175	75	30	35	65	250	855	1030	1185	1260	1650	24,835	8.7
		PM	1715	1730	1760	1970	1780	1760	1355	1270	1230	1335	1065	975		
06-07-75	SAT	AM	520	375	190	95	45	65	120	360	590	905	1185	1490	24,205	8.3
		PM	1690	1785	1830	1840	1865	1825	1615	1305	1200	1100	1125	1065		
06-08-75	SUN	AM	735	415	270	95	65	65	110	220	375	785	1020	1200	21,150	7.9
		PM	1645	1635	1615	1670	1785	1695	1345	1265	1165	850	655	470		
06-09-75	MON	AM	235	130	75	25	30	75	295	855	1035	1110	1245	1615	21,250	7.4
		PM	1600	1555	1555	1585	1600	1670	1205	1080	910	910	500	355		
06-10-75	TUE	AM	245	135	70	35	25	75	280	925	1110	1130	1340	1600	22,635	8.3
		PM	1680	1555	1685	1880	1705	1770	1310	1095	995	870	620	500		
06-11-75	WED	AM	275	160	75	45	20	70	270	880	1070	1135	1305	1670	22,655	7.8
		PM	1615	1550	1750	1730	1735	1665	1190	1145	940	945	825	590		
06-12-75	THU	AM	365	220	105	50	35	65	260	760	1040	1100	1320	1545C	22,135 C	8.0
		PM	1655C	1535C	1560C	1580C	1690C	1815C	1280C	1040C	970C	910C	735C	500C		

215,535 TOTAL COUNT

Problems such as this occurred so frequently that is was not feasible to discard these counts in favor of complete ones. Instead, it was necessary to substitute others to arrive at a complete set of counts. Three different procedures were used to complete the data sets. They are discussed below in descending order of their desirability:

- When between one hour and two days data are missing or incorrect, data from the corresponding time period in the preceeding or following week was used.
- When more than two days data were unavailable, a week in the preceeding or following month was used.
- When neither of those options were available, a week from the preceeding or following season was substituted.

Table 4 shows the locations of the complete traffic counts that were used in the grid square classification process.

These traffic data were then entered into the computer which plotted the hourly volume distributions for the traffic in each grid square. For each square, one set of curves was drawn for freeways and one set for surface streets. Figure 6 shows an example of weekday curves which represent the average traffic flow pattern for the five weekdays, Monday through Friday, and Figure 7, weekend curves, the average flow patterns for Saturday and Sunday. Seasonal variations are also shown.

These curves were compared with one another to detect common patterns. The average of all patterns with similar variations were combined to form a new distribution called a <u>traffic pattern type</u>. That is, the traffic pattern type curve represents the mean flow characteristics of several grid squares, all of which have similar distributions. Figure 8 illustrates the result of combining similar traffic pattern types.

The following procedures were used to arrive at these classifications:

- The classifications were based primarily on the weekday patterns; considerable variations in the weekend distributions were allowed.
- The curves were classified solely on the basis of their shape without regard to the geographical area they represented.

Table 4. Traffic Count Station Locations

Performing Agency	Station Location	Grid Square
Cal Trans	Santa Monica Fwy west of Hoover Ave	380,3760
	Harbor Fwy south of Slauson Ave	380,3760
	Harbor Fwy south of junction Rte. 10	380,3760
	Santa Monica Fwy east of National Blvd	370,3760
	Santa Monica Fwy west of Crenshaw Ave	370,3760
	Harbor Fwy south of El Segundo Ave	380,3750
	Harbor Fwy north of 76th St	380,3750
	Foothill Fwy at Brand Ave	380,3770
	San Diego Fwy east of Vermont Ave	380,3740
	San Diego Fwy east of Crenshaw Ave	370,3740
	Santa Ana Fwy at Magnolia	370,3780
	Harbor Fwy at C St	380,3730
	Riverside Fwy at the Newport Fwy	420,3740
L.A. County Traffic Dept.	Western and Imperial	370,3750
	Imperial and La Cienega	370,3750
	La Cienega and Romaine	370,3750
	Sepulveda and Vermont	380,3740
	Valley and Temple	380,3740
	La Brea and Slauson	370,3760
	Florence and Santa Fe	380,3750
	Slauson and Mansfield	370,3730

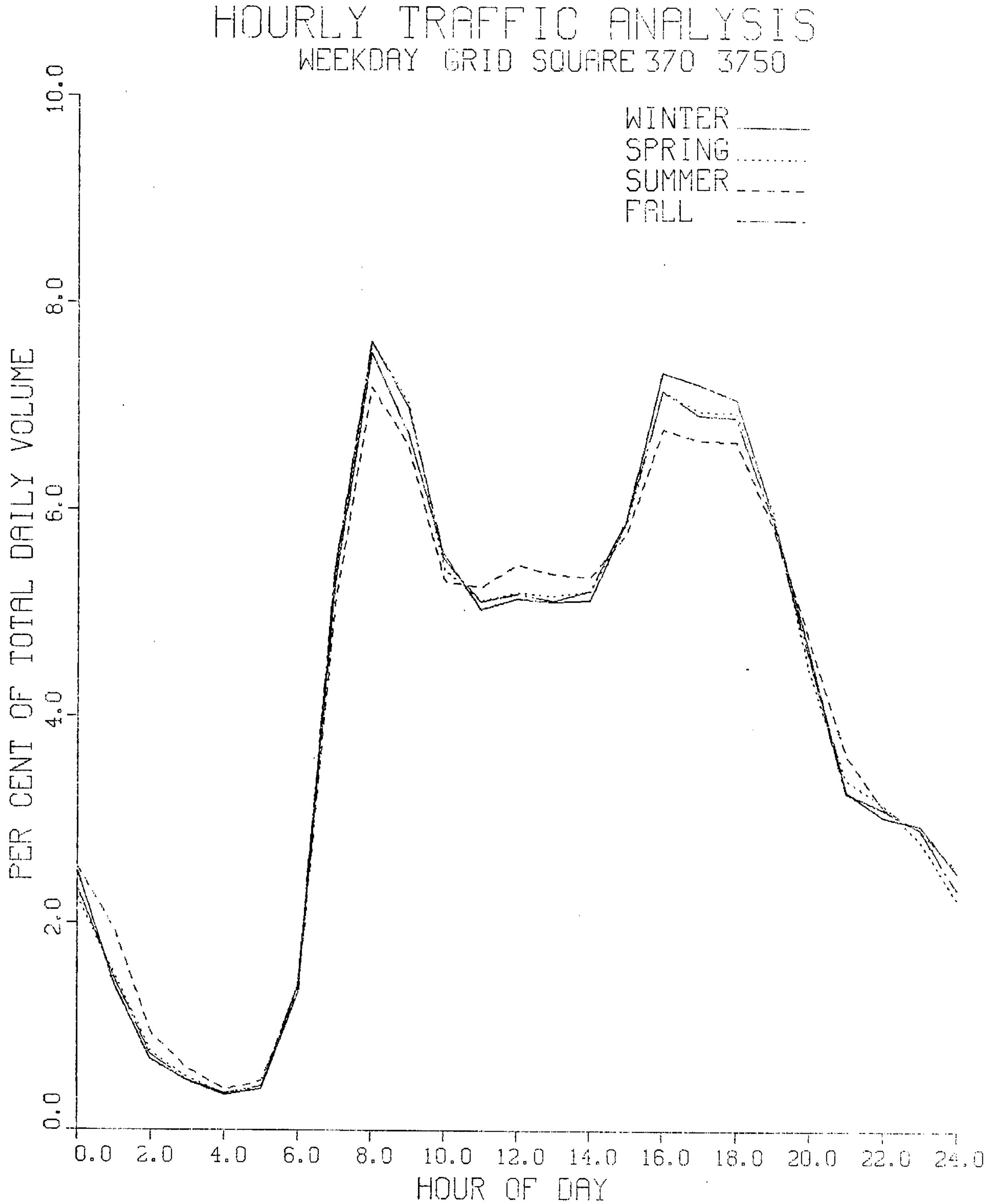


Figure 6. Example of Weekday Freeway Traffic Distribution

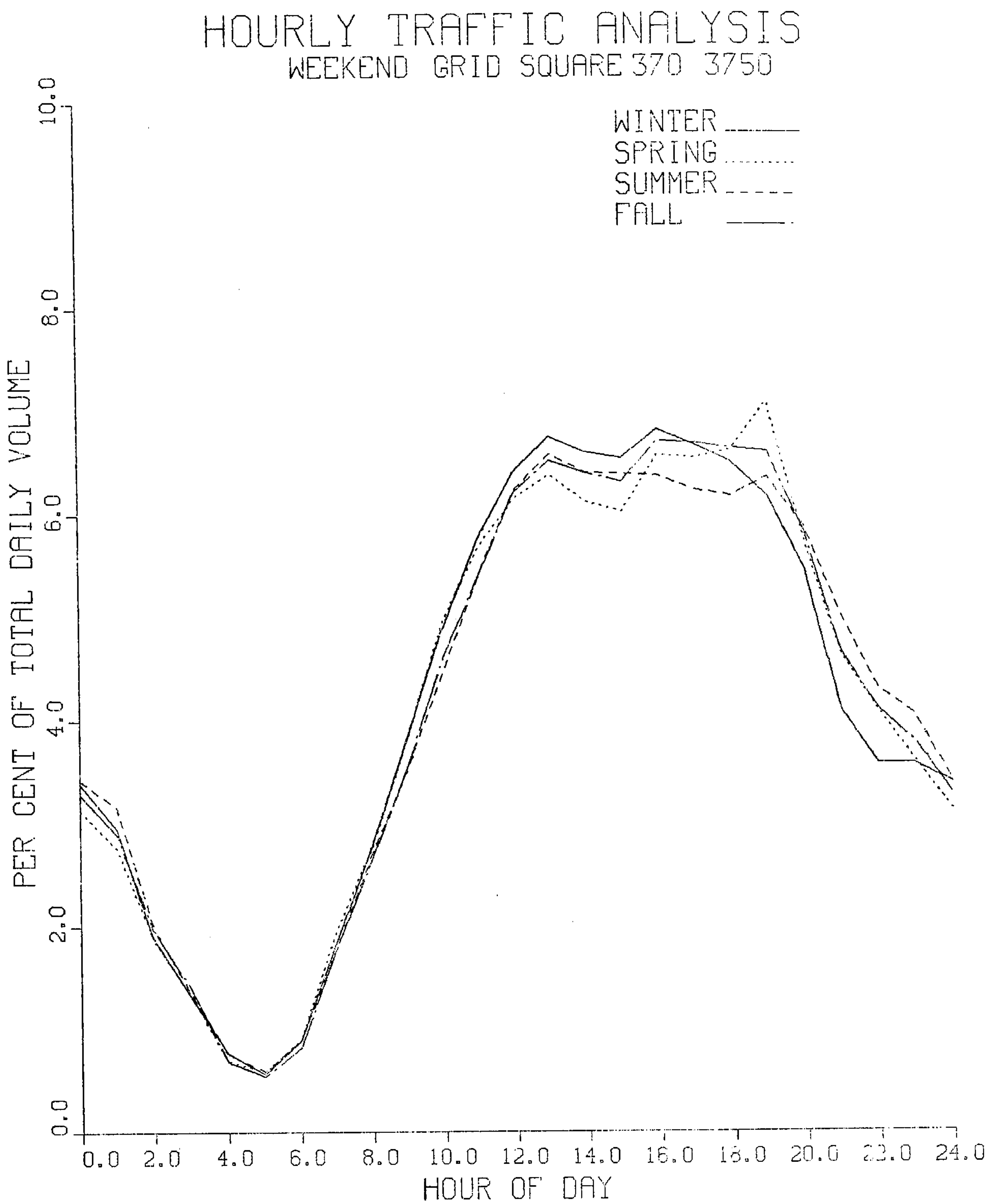


Figure 7. Example of Weekend Freeway Traffic Distribution

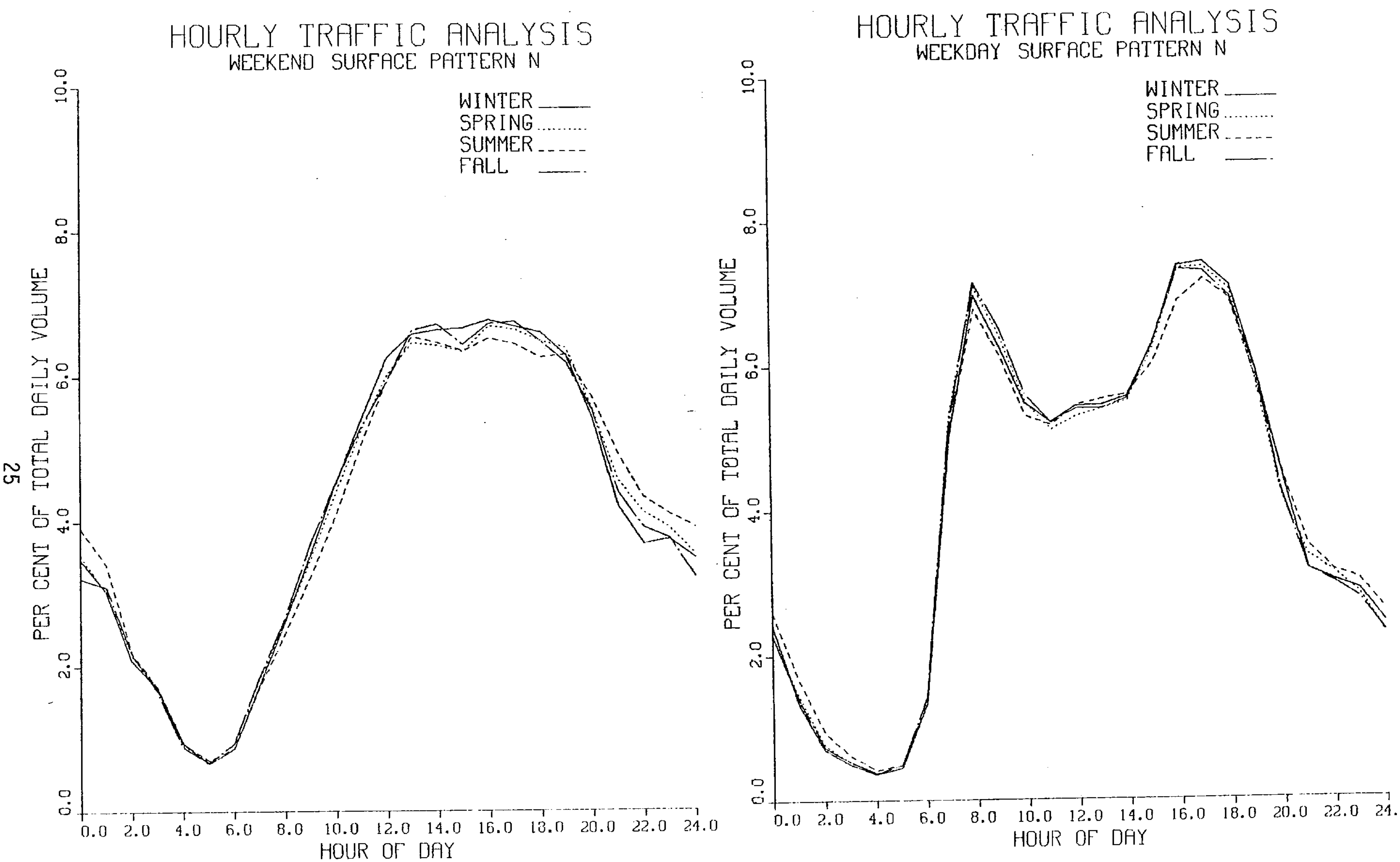
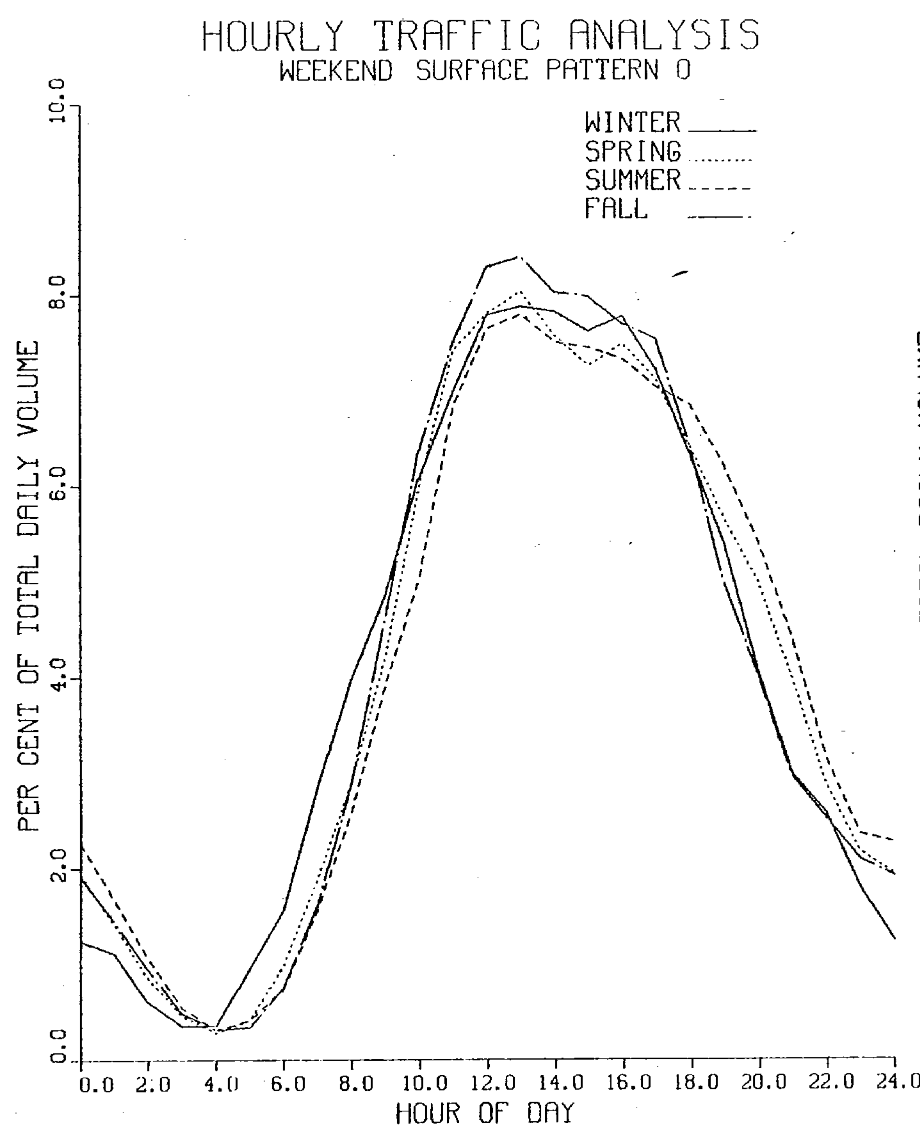


Figure 8. Traffic Pattern Types



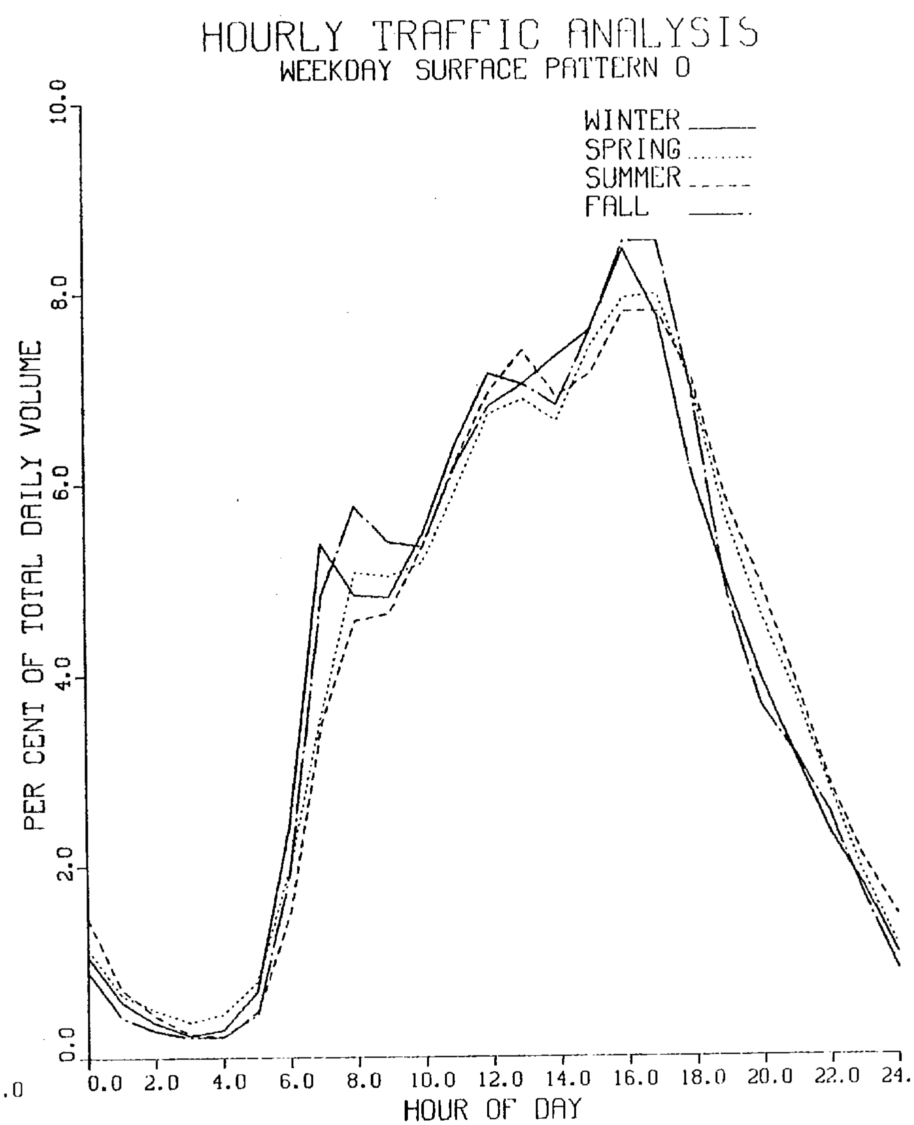


Figure 8. Traffic Pattern Types (Continued)

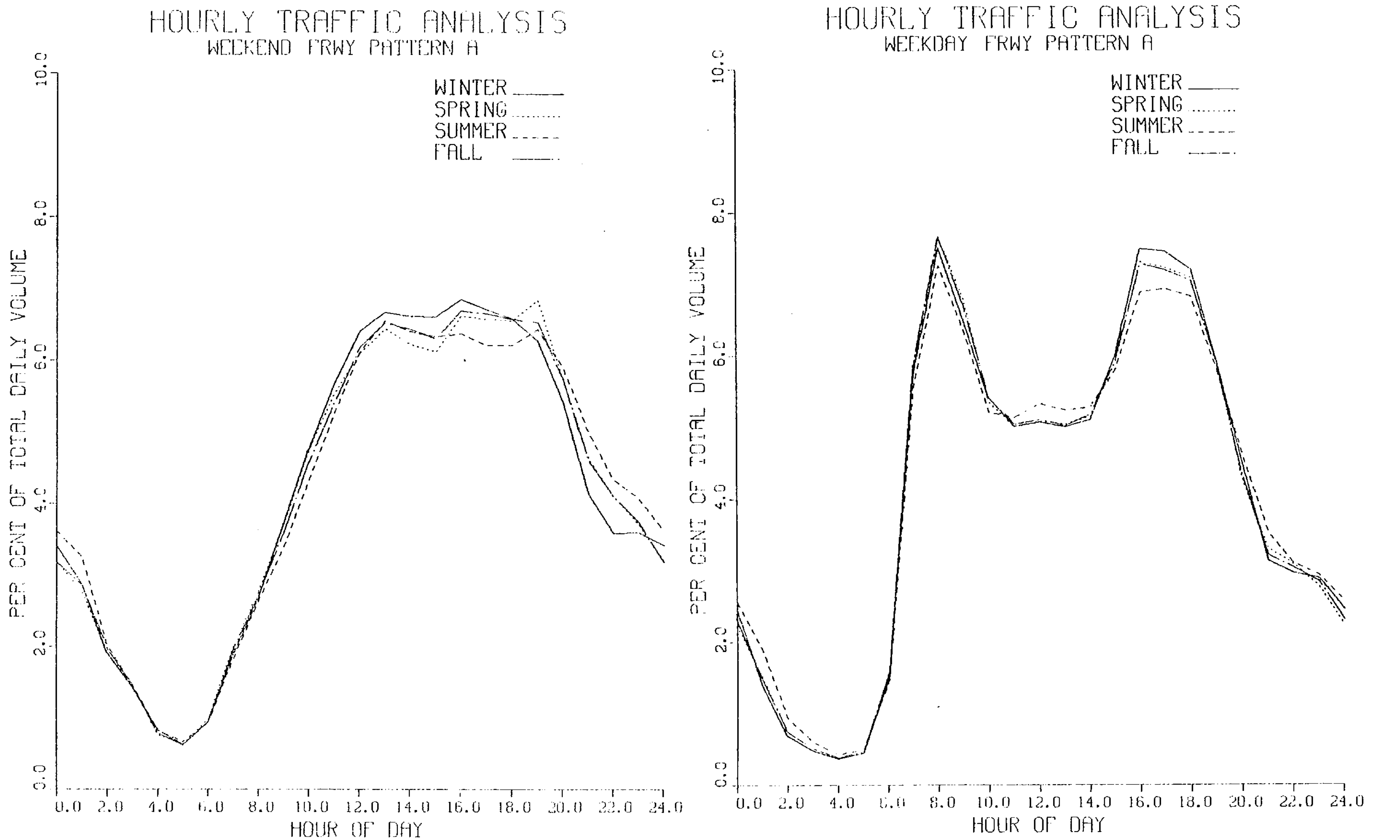


Figure 8. Traffic Pattern Types (Continued)

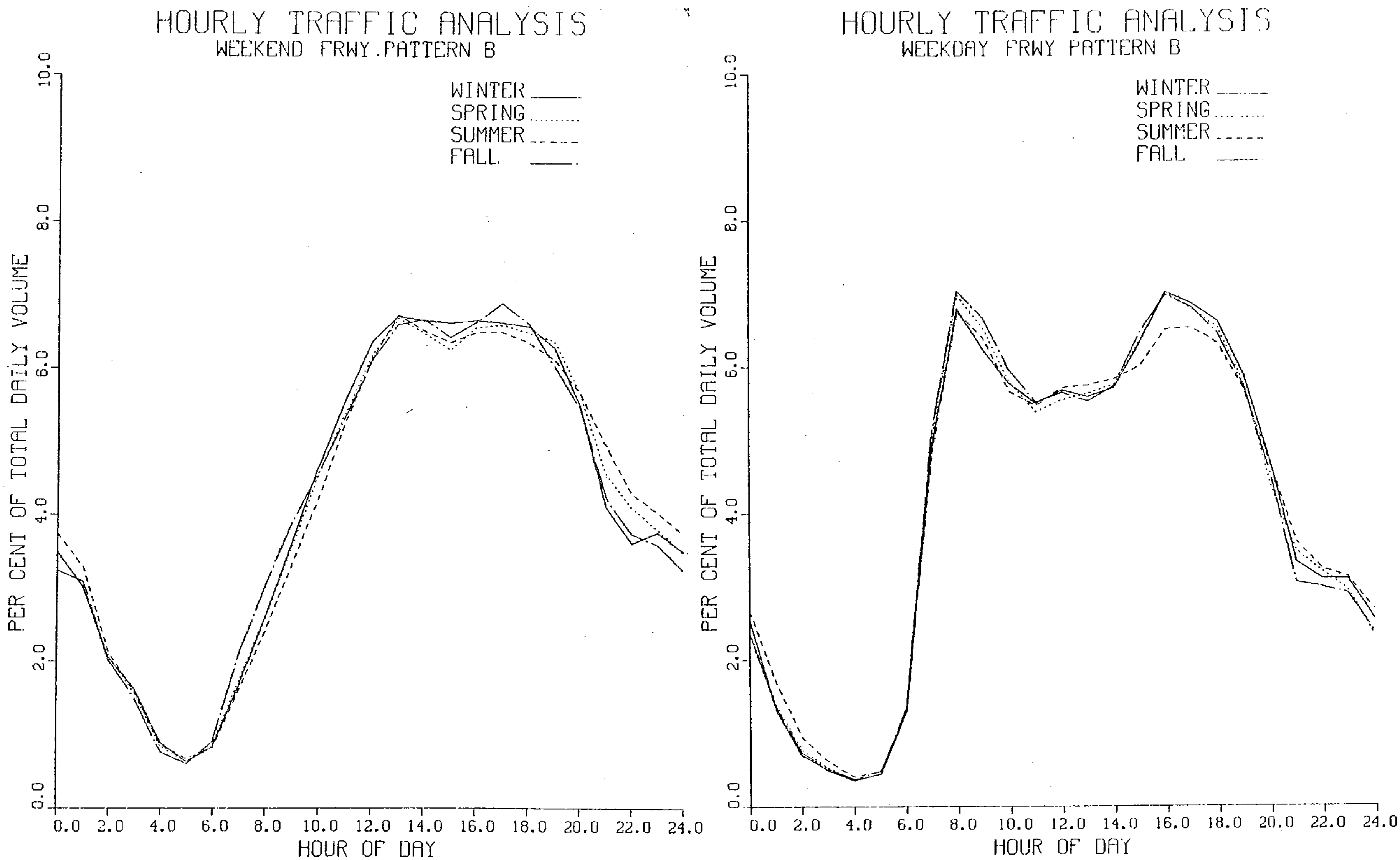


Figure 8. Traffic Pattern Types (Continued)

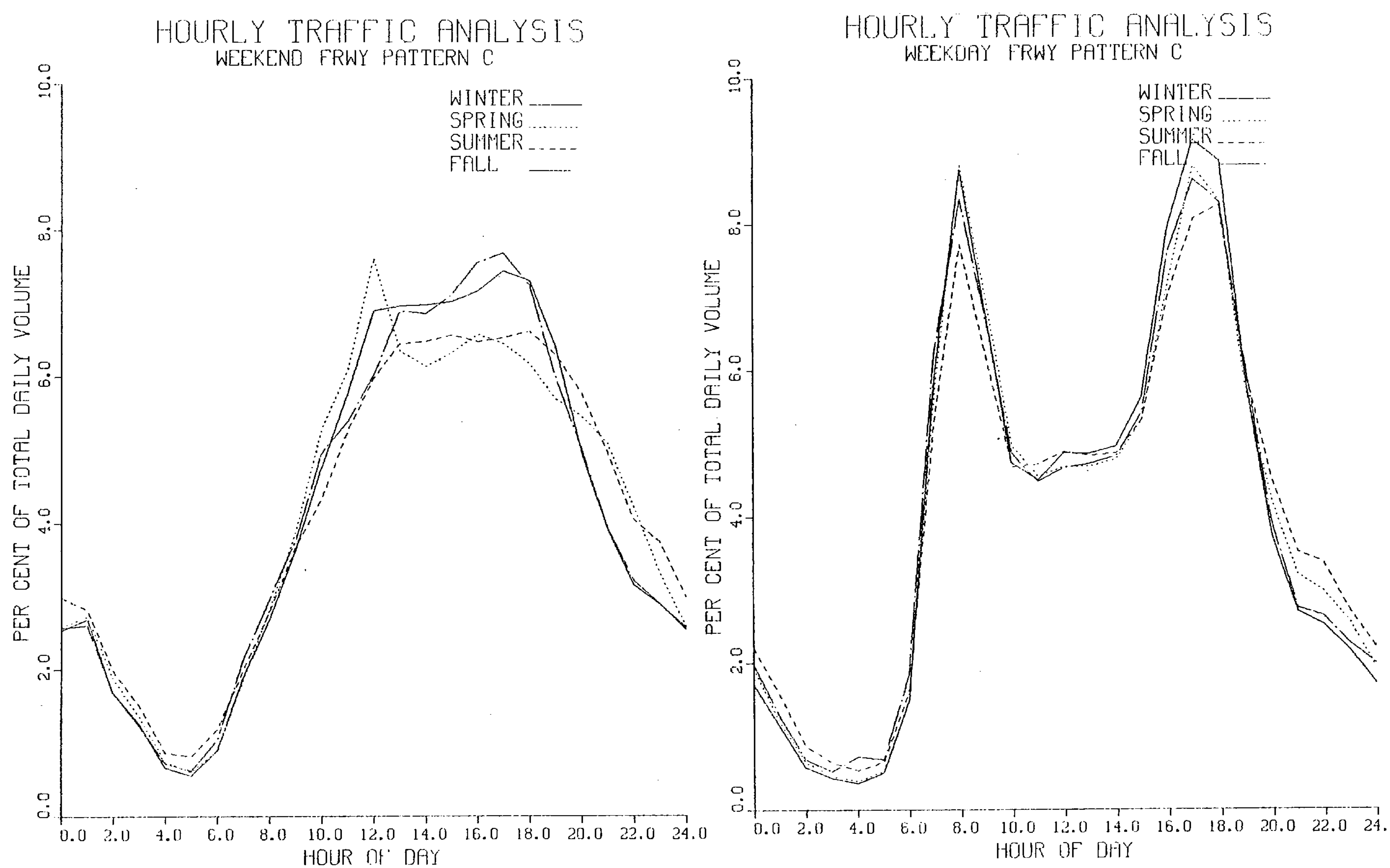


Figure 8. Traffic Pattern Types (Continued)

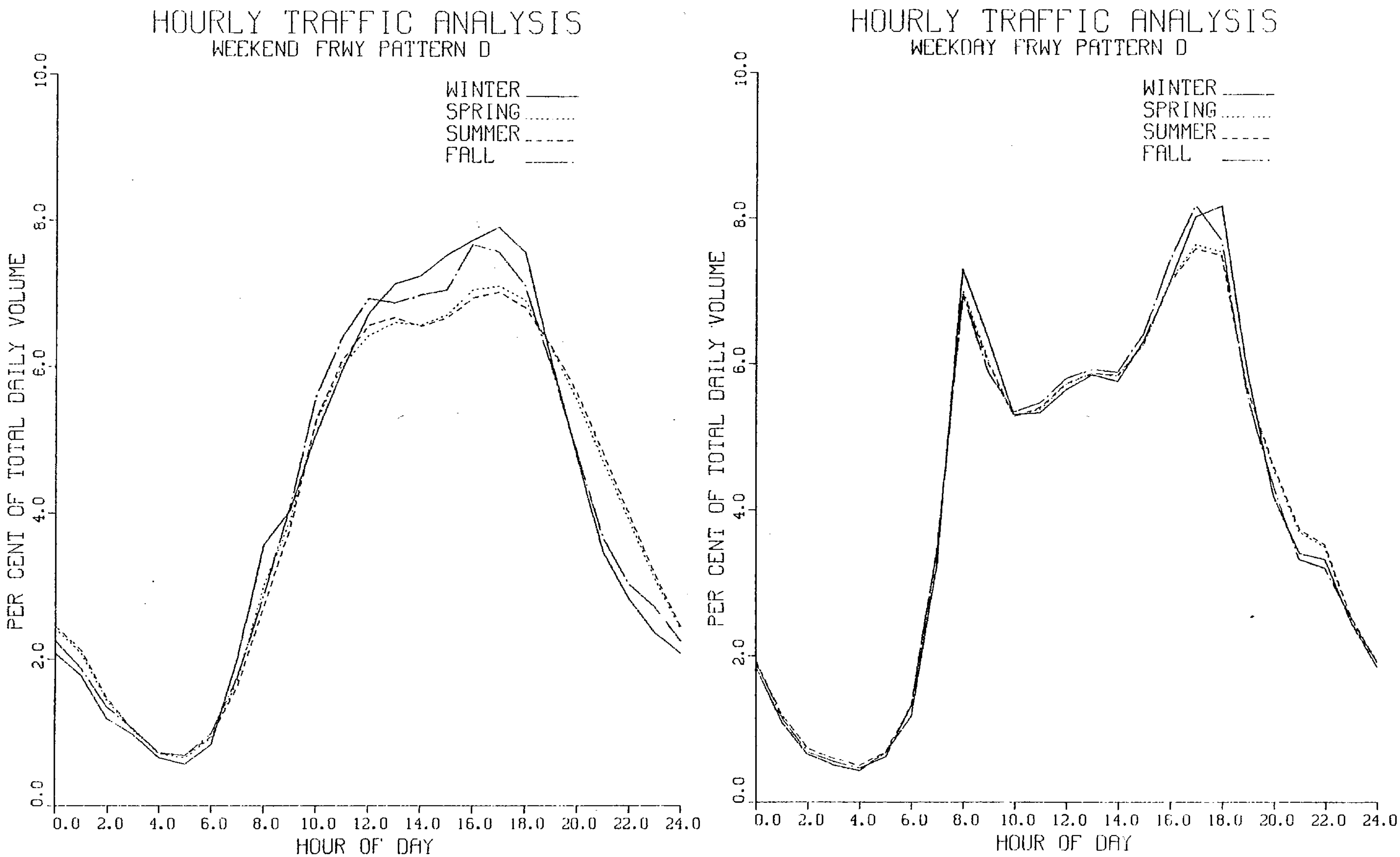


Figure 8. Traffic Pattern Types (Continued)

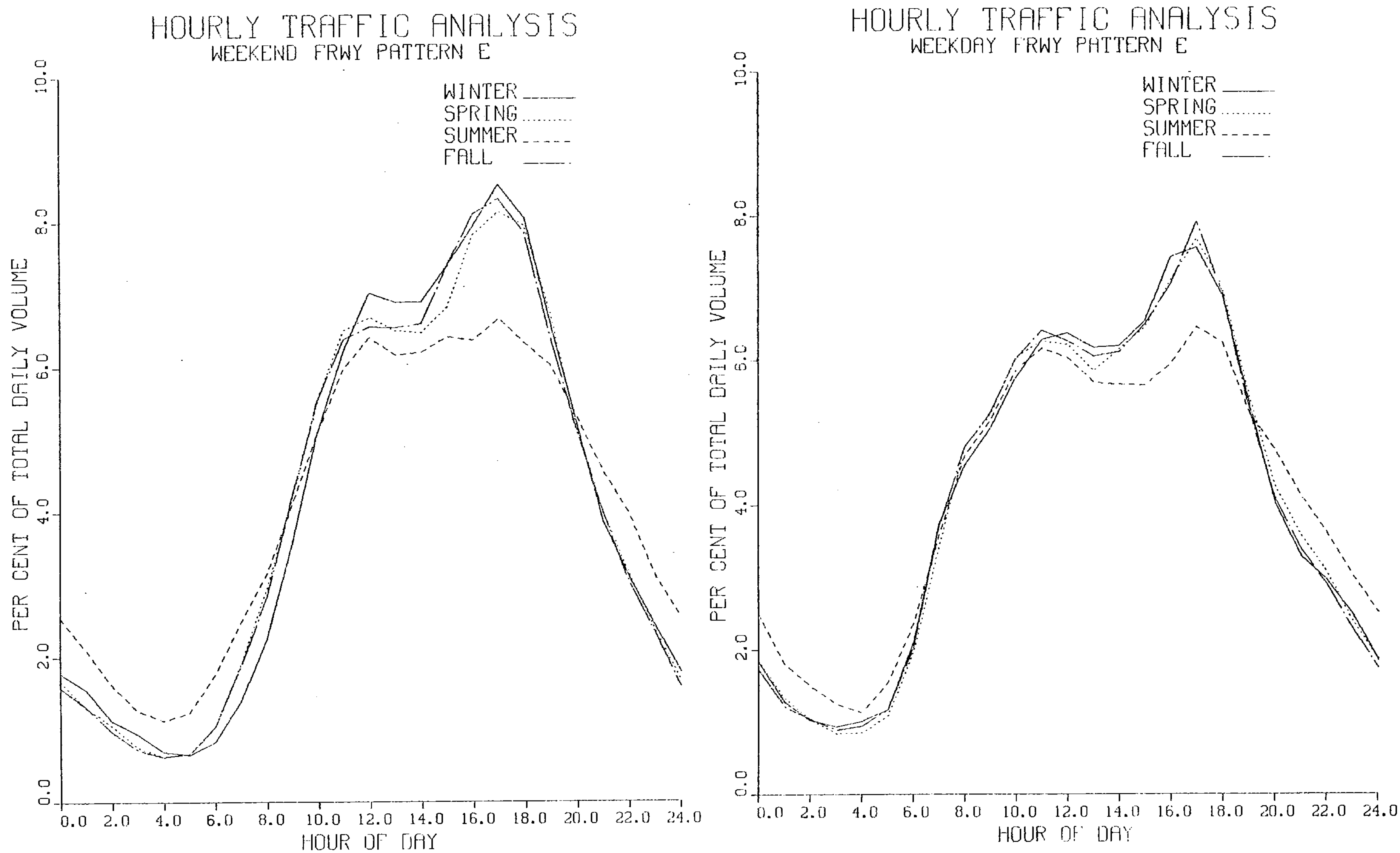


Figure 8. Traffic Pattern Types (Continued)

- The number of traffic pattern types was determined by the number of different distribution patterns detected; no set number of patterns was selected ahead of time.

Figure 9 shows a map of the SCAB illustrating the grid squares which constitute freeway traffic pattern types A through E. Table 5 presents the general characteristics of each traffic flow pattern. Although classification was done without regard to geographical location, the patterns show a strong correlation to location. Figure 10 shows a similar map for surface streets for which only two, clear traffic pattern types emerged.

Table 5. Traffic Pattern Characterization

Traffic Pattern	Characteristics
Freeway	
Type A	A strong north-south freeway traffic flow
Type B	A strong east-west freeway traffic flow
Type C	No strong north-south or east-west freeway traffic flow
Type E	Freeway traffic flow in rural areas
Surface Street	
Type N	Urban surface street traffic flow
Type O	Rural surface street traffic flow

Figure 11 defines the location of each of the five grid square types. Each grid square type, consists of a unique combination of a particular freeway traffic pattern type and a particular surface street traffic pattern type.

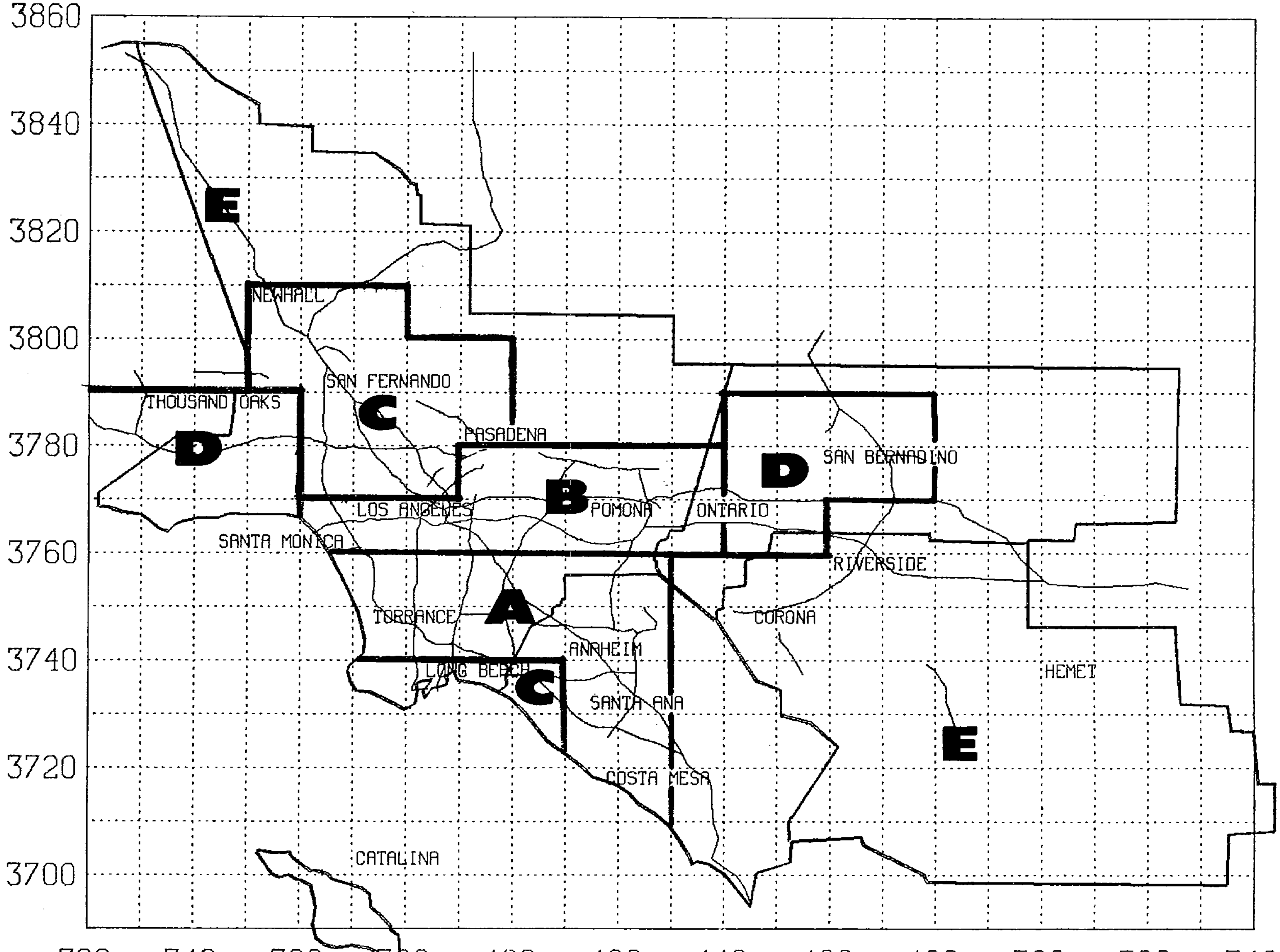


Figure 9. Freeway Traffic Type Zones

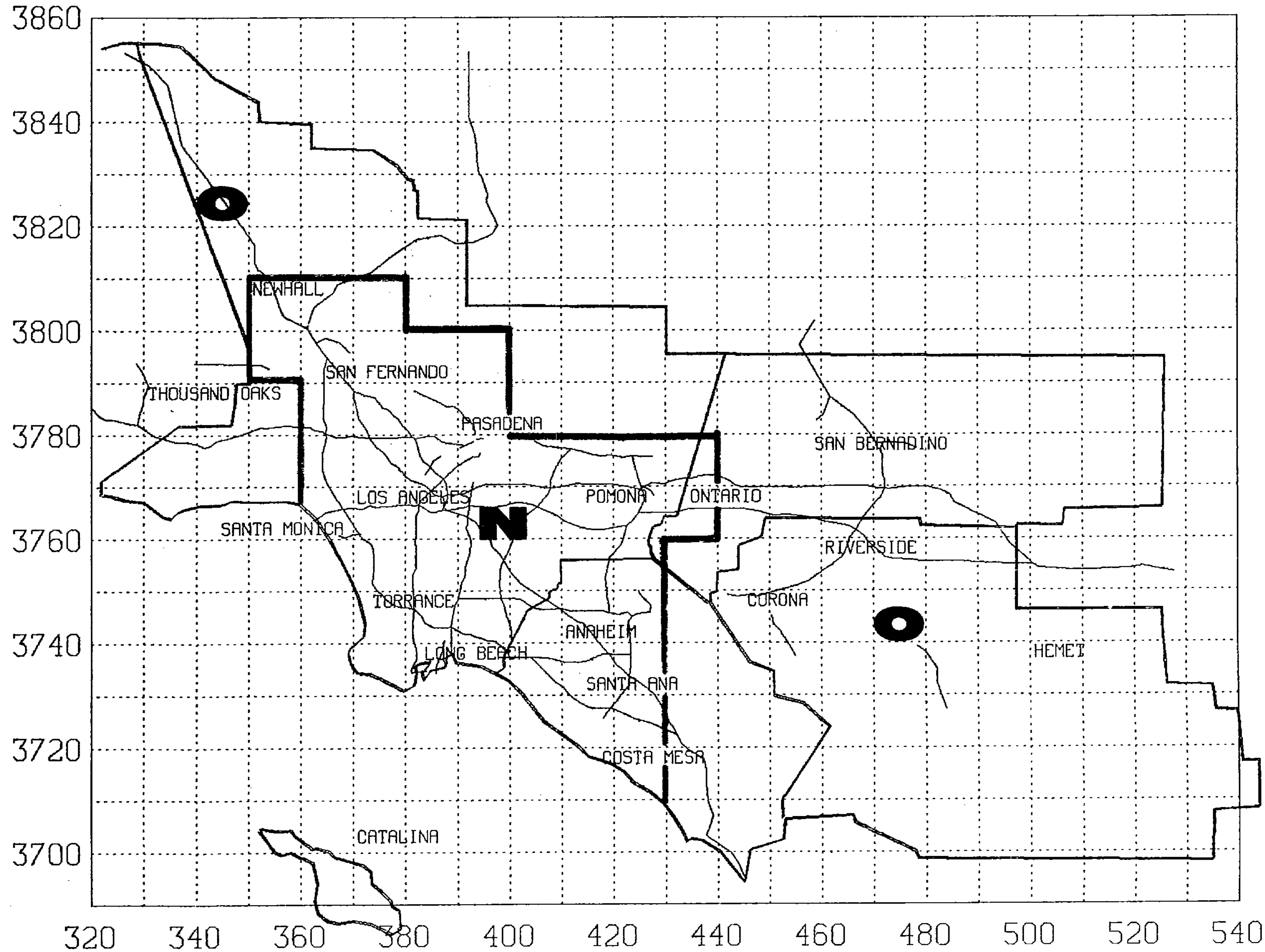


Figure 10. Surface Street Traffic Type Zones

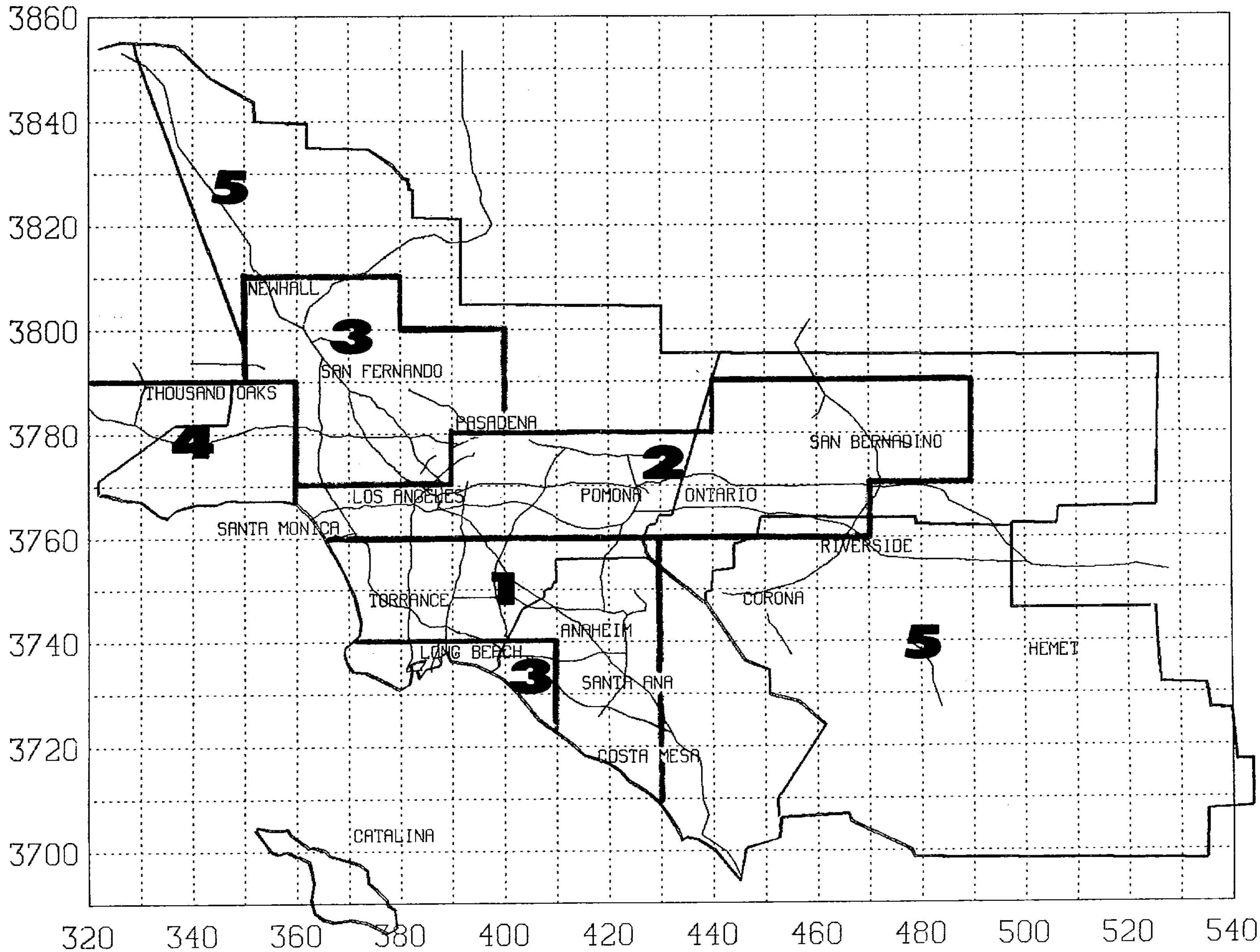


Figure 11. Grid Type Zones

For each grid square type, a set of disaggregating factors was developed. These factors when multiplied by the average weekday annual daily traffic volume provide estimates of seasonal, day-of-week and hourly variations in traffic volume. This is given by

$$V_{hsdrg} = AADT*SF_{srg}*WF_{drg}*HF_{hrg}$$

where

V_{hsdrg} = is the traffic volume for
- r road type (freeway, non-freeway)
- s season (winter, spring, summer, fall)
- d day (weekend, weekday)
- h hour of day (1-24)
- and g grid square type (1-5)

AADT = annual average daily weekday traffic

SF_{srg} = season factor

WF_{drg} = weekday, weekend factor

HF_{hrg} = hourly factor

The result of this procedure is to disaggregate each AADT link estimate into 192 hourly traffic estimates which reflect seasonal and daily variations in traffic volume (4 seasons, 2 day types, 24 hours). With these factors applied to each link in the traffic network, a model of traffic flow with a high degree of temporal and geographical resolution is obtained. It should be noted that the number of disaggregating factors is not fixed, thus providing a high degree of flexibility in resolution.

Vehicle Population and Mileage Distributions

For any given automobile, a large number of variables are involved in determining its expected emissions. The most significant, however, is the vehicle's model year. Because automobile emission regulations have been applied incrementally on the SCAB automobile population, there are a variety of emission control combinations and, therefore, a variety of expected emissions. This is reflected in the number of model year dependent emission factors required. In addition to knowing the vehicle model year distribution in the inventory, it is also necessary to know what fraction of the VMT each model year contributed. For these reasons, both the vehicle population and mileage distributions by model year must be known.

The 1975 inventory consists of estimates of average emissions for each quarter of the year as well as average annual emissions. The vehicle population distribution for each of the quarters then must properly reflect the introduction of new vehicles into the population and the scrappage of older model year vehicles. Using vehicle registration data and the following assumptions, annual scrappage rates for each model year can be determined.

- Scrappage rate is linear with age.
- The monthly scrappage rate is constant over a year.
- Vehicles which are zero and one year old in 1975 (i.e., 1975 and 1976 model year vehicles) are not scrapped.

An estimate of the total vehicle scrappage for a year is obtained from vehicle registration data

$$S = R_i - R_f - R_n$$

where

S = is the total number of vehicles scrapped during the year.

R_i = is the total number of vehicles registered at the beginning of the year.

R_f = is the total number of vehicles registered at the end of the year.

R_n = is the total number of vehicles registered for for the first time during the year (i.e., new vehicles).

The annual scrappage rate is then

$$S_y = S/R_i$$

Assuming the scrappage rate for each model year is linear with age and zero and one year old vehicles are not scrapped, the scrappage rate per year is given by

$$S_{ym} = \frac{2*S_y}{(n-1)}$$

where

S_{ym} = is the annual scrappage rate per model year (age).

S_y = is the total vehicle annual scrappage rate.

n = is the maximum age assumed for any vehicle.

The introduction of new vehicles into the population can be determined with the following assumptions:

- The number of out-of-state vehicles registered for the first time is negligible and will be ignored.
- All new vehicle sales are assumed to be current model year (i.e., 1975) until October.
- All new vehicle sales are assumed to be next year models (i.e., 1976) entering the population from October through December.

Having established the model year distribution (or age distribution) of the vehicle population, the mileage distribution for each model year can be determined. Estimates of annual mileage as a function of vehicle age have been made using data accumulated during an emissions test program conducted by the ARB. As the emissions tests were being conducted, the odometer reading of each vehicle was recorded. The mileage charts were then analyzed and a series of estimates of mileage based on vehicle age were developed. From these estimates and the model year distribution, the VMT distribution can be determined.

Estimation of Emissions

The estimation of emissions resulting from an activity (such as combustion or industrial production) involves the use of an emission factor. Emission factors are a statistical average or a quantitative estimate of the rate at which a pollutant is released to the atmosphere as a result of the source activity. The exhuast emission factor for highway vehicles, for example, is given in terms of mass pollutant emitted per unit distance traveled (i.e., grams of carbon monoxide/vehicle mile traveled). By multiplying the emission factor times the level of source activity, the total emissions from a source may be estimated.

The majority of mobile source emission inventories which have been previously compiled use the exhaust emission factor generation procedures and data contained in Reference (3). The procedure involves modifying a specific test cycle emission rate with factors to account for differences in average vehicle speed, ambient temperature, ratio of hot and cold operation and vehicle population mix. The test cycle employed in Reference (3) is the Federal Test Procedure which represents a specific series of driving modes (accelerations, decelerations, cruises and idles) representing a typical driving pattern for the United States. The emission factor for this test cycle corresponds to a particular average speed (19.6 mph), hot/cold operation (20 percent cold operation and 80 percent hot operation), and temperature range (68-86°F). The correction factors were derived to modify the test cycle emissions when the above parameters for a specific case differ from the test cycle values.

The derivation of the speed correction factors in Reference (3) utilizes national driving pattern data combining freeway and non-freeway driving. Urban driving pattern data were collected and processed to produce speed-mode matrices. The matrices are a statistical representation of the driving patterns. From these matrices, statistically representative driving cycles can be generated. Having established representative driving cycles at various average speeds, the emissions resulting from each cycle for eleven vehicle groups was estimated by the EPA modal emissions model (5). The relation between emissions and average speed for each vehicle group was then determined by a regression analysis. The relationships were then normalized to the FTP average speed (19.6 mph).

The 1975 FTP requires that emissions measurements be made within the limits of a relatively narrow temperature band (68 to 86°F). Such a band facilitates uniform testing in laboratories without requiring extreme ranges of temperature control. Present emission factors for motor vehicles are based on data from the standard Federal test (assumed to be at 75°F). Study indicates that changes in ambient temperature result in significant changes in emissions during cold start-up operation. Because many Air Quality Control Regions have temperature characteristics differing considerably from the 68 to 86°F range, the temperature correction factor should be applied.

The 1975 FTP measures emissions during: a cold transient phase (representative of vehicle start-up after a long engine-off period), a hot transient phase (representative of vehicle start-up after a short engine-off period), and a stabilized phase (representative of warmed-up vehicle operation). The weighting factors used in the 1975 FTP are 20 percent, 27 percent, and 53 percent of total miles (time) in each of the three phases, respectively. Thus, when the 1975 FTP emission factors are applied to a given region for the purpose of assessing air quality, 20 percent of the light duty vehicles in the area of interest are assumed to be operating in a cold condition, 27 percent in a hot start-up condition, and 53 percent in a hot stabilized condition. For non-catalyst equipped vehicles (all pre-1975 model year vehicles), emissions in the two hot phases are essentially equivalent on a grams per mile (grams per kilometer basis). Therefore, the 1975 FTP emission factor represents 20 percent cold operation and 80 percent hot operation.

Many situations exist in which the application of these particular weighting factors may be inappropriate. For example, light duty vehicle operation in the center city may have a much higher percentage of cold operation during the afternoon peak when work-to-home trips are at a maximum and vehicles have been standing for eight hours. The hold/cold vehicle operation correction factor allows the cold operation phase to range from 0 to 100 percent of total light duty vehicle operations. This correction factor is a function of the percentage of cold operation and the ambient temperature.

To produce speed correction factors more representative of the SCAB, the procedure described above (with some variation) was carried out with driving pattern data collected specifically for this project.

To obtain these data, a chase car equipped with a digital data collection system was utilized. This system digitally records time of day, vehicle speed and associated fixed data such as weather conditions and route information. Using this vehicle, the chase-vehicle driver emulates the driving behavior of random samples of vehicles along the route. These data were then processed to provide a statistical representation of the LDV driving patterns encountered in the SCAB. As discussed above and in Reference (6), these data are used to generate driving cycles which are representative of light duty vehicle operation in the South Coast Air Basin. The representative driving cycles were then input into the EPA modal emissions model (5) and emissions were estimated as a function of average route speed.

The above program was conducted by Olson Laboratories, under a separate contract, and a detailed description of this program is contained in Reference (7). The data supplied by Olson Labs for the generation of speed correction factors included emission factors for each of eight California vehicle groups and the average speed for each of the 180 driving cycles for both freeway and non-freeway driving data. The emissions data were direct outputs from the EPA modal emissions model and therefore represent hot operation for each of the vehicle groups for calendar year 1972. Inasmuch as these data will be normalized and both the hot/cold factor and deterioration factor are constants, the emissions data were not modified. One important difference, however, does exist between the procedure in (3) and the procedure employed for this study. The generation of speed correction factors was not limited to the use of only representative cycles. The driving cycles used to generate emissions at the various speeds were random samples of the speed-mode matrices. The use of "representative" driving cycles to develop emission factors implies that a "most probable" driving cycle taken from a population of all possible driving cycles on a road, will also represent the "most probable" emissions on that road. Two factors must be considered for the above assumption. First, for a particular average speed driving cycle, the emissions for any specific vehicle could vary considerably for different modes making up the driving cycle even though the average speed is the same. For example, idle for five minutes, accelerate 0-60 mph in one minute and 60 mph cruise for four minutes would yield different emissions than an acceleration of 0-30 mph in 30 seconds, and 30 mph cruise for 0.9 minutes even though the average speed is the same. Second, the average speed on any roadway is generally composed of a distribution of individual vehicle average speeds with each average speed contributing differently to the emissions.

The effect of these two factors on emission estimation has not been specifically addressed in any previous analysis. The methodology to be employed in this project will follow the currently established methodology with the exception of using "representative" driving cycles, recognizing that further analysis into the above mentioned factors should be performed.

The composite emission factors for light duty vehicles (LDV) are given by

$$e_{npstwx} = \sum_{i=n-18}^{n} c_{ipn}\ m_{in}\ v_{ips}\ z_{ipt}\ r_{iptwx}$$

where

e_{npstwx} = Composite emission factor in (g/mi) for calendar year n, pollutant p, average speed s, ambient temperature t, percent cold operation w, and percent hot start operation x.

c_{ipn} = The FTP (1975 Federal Test Procedure) mean emission factor for the i^{th} model year light duty vehicles during calendar year n and for pollutant p.

m_{in} = The fraction of annual travel by the i^{th} model year light duty vehicles during calendar year n.

v_{ips} = The speed correction factor for the i^{th} model year light duty vehicles for pollutant p and average speed s.

z_{ipt} = The temperature correction factor for the i^{th} model year light duty vehicles for pollutant p and ambient temperature t.

r_{iptwx} = The hot/cold vehicle operation correction factor for the i^{th} model year light duty vehicles for pollutant p, ambient temperature t, percent cold operation w, and percent hot start operation x.

The emissions factors were obtained as follows:

c_{ipn} = Is tabulated by model year, pollutant and calendar year.

m_{in} = Is computed by multiplying the fraction of i model year LDV's operating in the SCAB in calendar year n by the average annual mileage of an i model year LDV in SCAB divided by the average number of miles by all LDV's.

v_{ips} = Is computed for hydrocarbons and carbon monoxide by the equation below:

$$v_{ips} = e^{(A_{ip} + B_{ip}S + C_{ip}S^2)}$$

where A_{ip}, B_{ip} and C_{ip} were derived specifically for the SCAB from the chase car program. For NO_x the equation is in of the form:

$$v_{ips} = A_i + B_iS$$

where A_i and B_i were also derived from the chase car program.

z_{ipt} = Is computed by the equation:

$$z_{ipt} = A_{ip}t + B_{ip}$$

The coefficients A_{ip} and B_{ip} are tabulated by model year and pollutant. The model year is considered in the temperature factor only in the determination of catalyst/non-catalyst factors. All model years prior to 1975 are assumed to be non-catalyst.

r_{iptwx} Is computed for non-catalyst LDV's by:

$$r_{iptwx} = \frac{W + (100-W)f(t)}{20 + 80f(t)}$$

where

$$f(t) = A_pt + B_p$$

For catalyst LDV's

$$r_{iptwx} = \frac{W + (X)f(t) + (100-W-X)g(t)}{20 + 27f(t) + 53g(t)}$$

where f(t) is the same as above and

$$g(t) = A_pt + B_p$$

for exhaust hydrocarbons and nitrogen oxides.

For carbon monoxide:

$$g(t) = e^{(A_pt + B_p)}$$

Average rather than composite emission factors are used for sulfur dioxide, particulates and crankcase hydrocarbons.

Exhaust emissions are expressed in terms of grams of pollutant per vehicle mile traveled. However, for diurnal and hot-soak evaporative hydrocarbon emissions, the usual measure is grams of pollutant per vehicle per day and grams of pollutant per vehicle trip, respectively. Because the spatial and temporal resolution of the inventory is derived from VMT distributions, some means of distributing evaporative emissions must be developed. For diurnal emissions, it can be assumed that the automobile population is distributed spatially in the same manner as the general population. The general population distribution can easily be determined on a grid square basis from population density maps.

The average diurnal emission factor is given by

$$e_d = \sum_{i=n-18}^{n} g_i a_i$$

where

g_i = The diurnal evaporative emission factor for model year i in gm/day.

a_i = The vehicle population distribution by model year.

The diurnal hydrocarbon emissions in grid square (j,k) are then given by

$$E_{jk} = N P_{jk} e_d$$

where

N = The total number of vehicles in the basin.

P_{jk} = The fraction of the people in grid square (j,k).

If hourly emission estimates are desired, then daily values are simply divided by 24.

Hot-soak hydrocarbon emissions are a function of the number of trips generated. It can be assumed that the trip distribution and the VMT distribution follow the same pattern, both spatially and temporarily if considered on a daily basis. The hot-soak emissions can also be assumed to be identical for each day of the year (i.e., no seasonal variation).

The average hot-soak emission factor is given by

$$e_n = \sum_{i=n-18}^{n} d_i M_{in} \qquad \text{gm/trip}$$

where

d_i = The hot-soak evaporative emission factor for model year i in gm/trip.

The hot-soak evaporative hydrocarbon emissions at hour ℓ in grid square (j,k) are then given by

$$E_{\ell jk} = e_n t_d \; N \; T_{\ell jk} \; V_{jk}/V_{tot}$$

where

t_d = The average number of trips per day for an LDV.

N = The total number of LDV's in the SCAB.

V_{jk} = The daily VMT in grid square (j,k).

$T_{\ell jk}$ = The hourly VMT factor for the grid square.

V_{tot} = The total VMT in the SCAB.

The first three parameters of the equation represent the total daily hot-soak emission in the basin. The ratio of the VMT in grid (j,k) to the total VMT apportions the daily emissions by VMT, and the time factor $T_{\ell jk}$ converts from daily to hourly emissions. The hourly time factor is again proportional to the hourly VMT.

Computer Software

The methodology of Reference (3) has been implemented in a computer model to provide a tool for the development of LDV mobile source emission inventories under various input conditions. Figure 12 illustrates the inventory development process. As the figure indicates, two parameters, VMT and the emission factor, are processed in a parallel fashion to account for season, time of day, operating conditions, vehicle population mix, etc. The process results in corrected values of VMT for grid square link and composite emission factors reflecting the modeled driving conditions. The end result is the emission in each grid square for the period of interest.

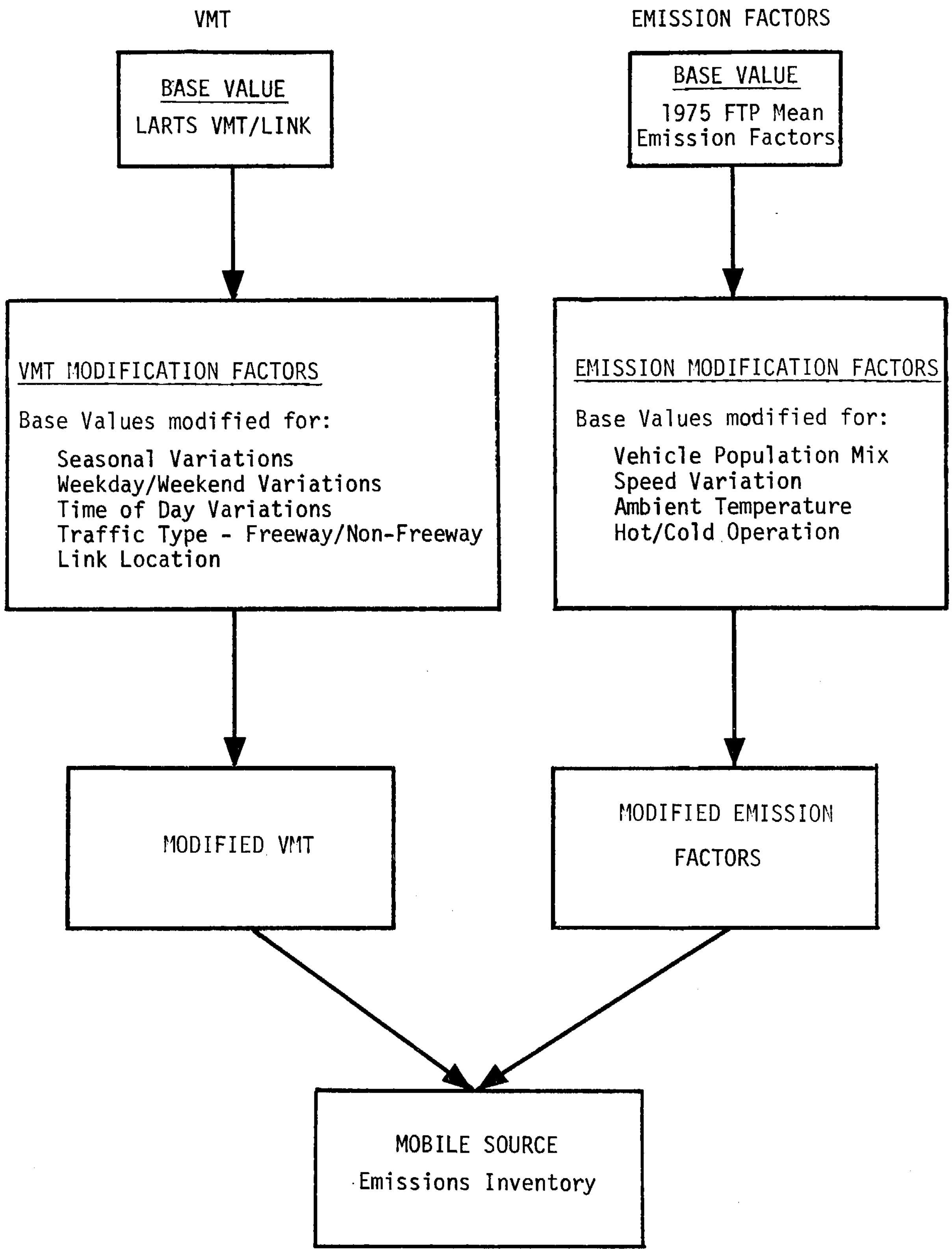


Figure 12. The Inventory Development Process

The model input variables are listed below by category.

Emission Types

NEMIS - Number of emission types

IEMISN(I) - Emission type = 1 Exhaust HC
= 2 CO
= 3 NOX
= 4 SOX
= 5 PART.
= 6 Evaporative HC
= 7 Crankcase HC
= 8 Total HC

Vehicle Population and Use

NVEH - Type of vehicle to be modeled = 1 LDP
= 2 LDT
= 3 HDV Gas
= 4 HDV Diesel
= 5 LDV Diesel
= 6 Motorcycle

The program is complete only for NVEH = 1 LDP
= 2 LDT

VMTDIS(I,J)- The average number of miles driven annually by an I-1 year old type J vehicle.

POPDIS(I,J)- The fraction of type J vehicles that are I-1 years old.

VEHDIS(J) - The fraction of all the vehicles that are type J

COLDOP(J) - Percent cold operation by vehicle type J

HOTSOP(J) - Percent hot start operation by vehicle type J

HOTCOP(J) - Percent hot cruise operation by vehicle type J

Grid Type

ITYPEG(I,J)- Type of grid which has its location specified by I and J. (1,1) is lower left hand grid shown in Figure 2.

Time to be Modeled

IYEAR - Year

NSESN - Number of seasons to be included. If more than one season is modeled, an averaging scheme is used to compute the factors.

ISESN(I) - The seasons to be modeled = 1 Winter
= 2 Spring
= 3 Summer
= 4 Fall

IDAY(I) - Weekday/weekend indicator

IDAY(1) = 1 include weekdays
IDAY(2) = 1 include weekends

IDAY(1) and IDAY(2) may both be set to 1 and the average day will be taken.

NTIME - Number of times of day to be modeled. One hour may be modeled or any subset of the 24 hours.

ITIME(I) - Times of day to be modeled = 1 the hour from Midnight to 1 A.M.
= 2 the hour from 1 A.M. to 2 A.M.
= 24 the hour from 11 P.M. to Midnight

Road Type

IRDTYPE - Road type to be modeled = 0 Non-freeway
= 1 Freeway only
= 2 Both non-freeway and freeway

Grid Square Definition

DXY - Dimension of each grid square (KM)

XMIN - Minimum East-West UTM coordinate (KM)

XMAX - Maximum East-West UTM coordinate (KM)

YMIN - Minimum North-South UTM coordinate (KM)

YMAX - Maximum North-South UTM coordinate (KM)

Ambient Temperature

TEMPER(N,I) - The temperature at time ITIME(N) and season ISESN(I). An average temperature is used if more than one time or season is considered.

VMT Factors

FSESNF(I,K) - The freeway seasonal VMT factor for season ISESN(I) and grid type K.

FSESNS(I,K) - The surface street seasonal VMT factor for season ISESN(I) and grid type K.

FDAYF(1,I,K) - The freeway weekday VMT factor for season ISESN(I) and grid type K.

FDAYF(2,I,K) - The freeway weekend VMT factor for season ISESN(I) and grid type K.

FDAYS(1,I,K) - The surface street weekday VMT factor for season ISESN(I) and grid type K.

FDAYS(2,I,K) - The freeway weekend VMT factor for time ITIME(N), season ISESN(I) and grid type K.

FTIMEF(N,I,K) - The freeway time-of-day VMT factor for time ITIME(N), season ISESN(I) and grid type K.

FTIMES(N,I,K) - The surface street time-of-day VMT factor for time ITIME(N), season ISESN(I) and grid type K.

GROWTH - The factor to be applied to the 1974 LARTS VMT to reflect the year modeled.

Speed Indices

IPKSPF(N,I,K) - Freeway peak speed flag = 0 use off-peak speed
= 1 use peak speed

For time ITIME(N), season ISESN(I) and grid type K.

IPKSPS(N,I,K) - Surface street peak speed flag for time ITIME(N), season ISESN(I) and grid type K.

The operation of the mobile source emissions inventory model is detailed in the flow diagram presented in Figure 13. An effort has been made to make the modules both independent and interpendent. An example of this is the VMT Aggregation Module (VAM). The VAM module provides speed and peak/off-peak and spatial distribution of VMT for each grid square type. These data serve as a direct input to the emission computation module. The model is also general in the sense that is may be used for all vehicle types assuming the appropriate input data are available.

The model is executed in four steps corresponding to the modules shown in Figure 13. This step-wise procedure not only allows for useful intermediate results, but also enables the user to locate errors or inconsistencies without exercising the entire model.

The first module, the VMT Aggregation Module simply reads the traffic model link tape and combines VMT which have a common grid square, speed, and road type into a VMT matrix. Four such VMT matrices are constructed corresponding to non-freeway off-peak conditions, non-freeway peak, freeway off-peak, and freeway peak conditions. These matrices contain the total VMT from all types of vehicles and can thus be used as a VMT basis for both LDP's and LDT's.

The Emission Factor Module (EFM) computes emission factors for:

- Exhaust Hydrocarbons
- Carbon Monoxide
- Oxides of Nitrogen
- Particulates
- Sulfur Dioxide
- Crankcase Hydrocarbons
- Evaporative Hydrocarbons
  - Diurnal
  - Hot-Soak

Composite emission factors reflecting speed, temperature and hot/cold operation are computed for exhaust HC, CO and NO_x. These composite factors are computed for each speed (15-60 mph in increments of 5 mph), each hour and each season for freeway and non-freeway driving patterns. Single value average emission factors are computed for the remaining pollutants.

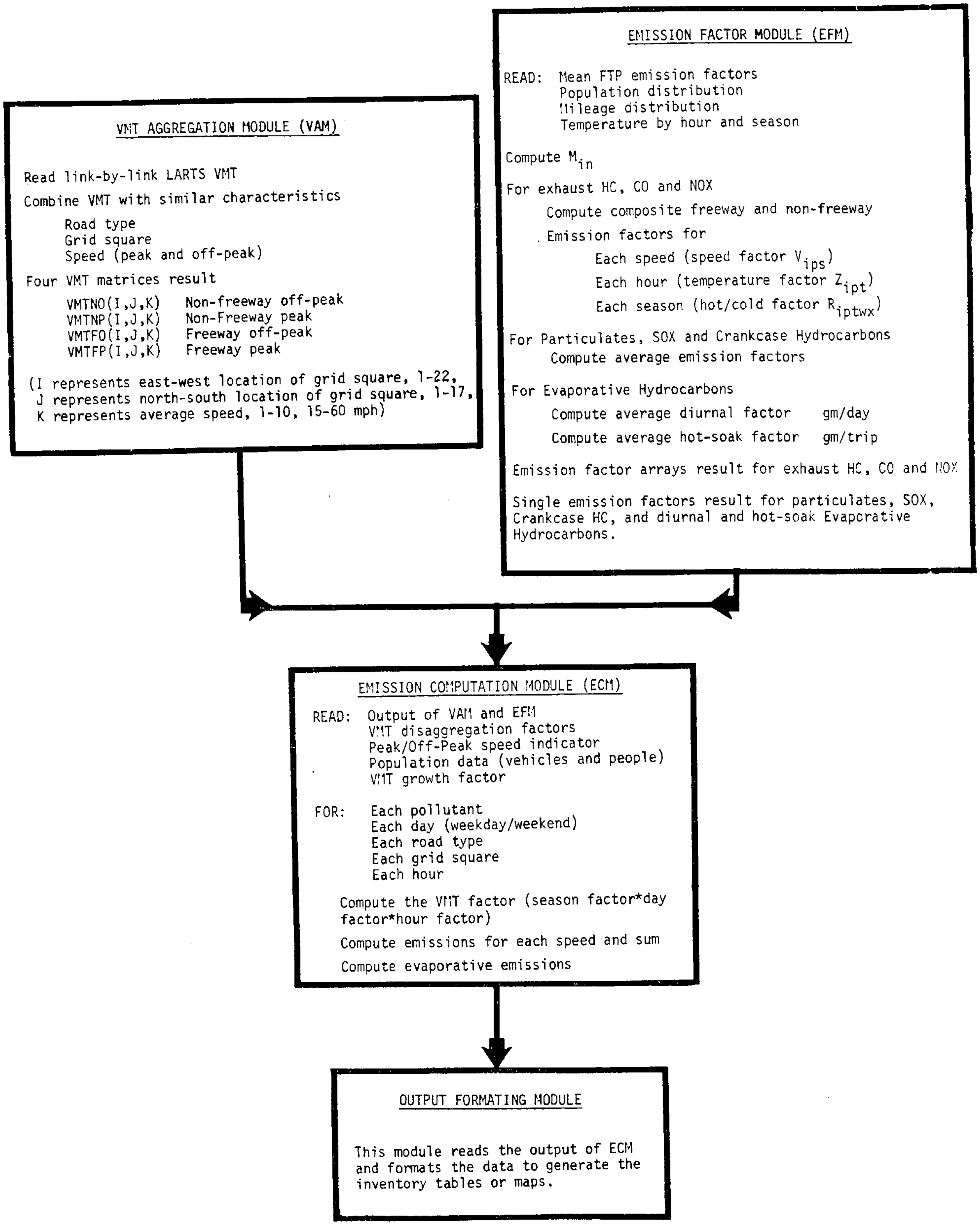


Figure 13. Emission Inventory Model Flow Diagram

The Emission Computation Module (ECM) combines the results of the VAM and the EFM along with the VMT disaggregation factors to construct the emissions inventory. This module computes emissions for each pollutant, each season, each day type (weekday/weekend), each road type, each grid square for each hour of the day. This module includes all the season, day and hour VMT factors, along with the VMT growth factor and the fraction of the VMT contributed by the vehicle type modeled. These factors, along with the VMT from the VAM, yield the disaggregated VMT. The proper emission factor from the emission factor array is chosen and the emissions are computed. The evaporative hydrocarbon emissions are calculated as discussed above. The results of the ECM module are output to tape. The tape is then read by the Output Formatting Module (OFM) and selected portions of the data are formatted into the inventory tables or the emissions maps.

4.0 RESULTS

Presented in this section are the results of implementing the methodology of the previous section. The input to the model and the resultant output represents a 1975 mobile source emission inventory for light duty vehicles in the South Coast Air Basin.

VMT Data Base

The VMT data base for the 1975 inventory consists of two components:

- Traffic network and associated road link annual average weekday traffic volumes.
- Disaggregating factors for each road type and grid type.

The traffic network and associated link volumes were derived from the LARTS 1974 model results. The traffic volumes represent weekday values. A VMT growth factor of 5.5% was recommended by CALTRANS for updating the VMT from 1974 to 1975. This factor is applied basin-wide and therefore does not account for route distribution changes which may occur. These changes are felt to be insignificant, however, relative to the inaccuracies inherent in the model itself. Table 6 presents a summary of the basin-wide VMT for the 1975 light-duty vehicle inventory. The distribution of

Table 6. VMT Summary

County Vehicle Type	VMT~(Million Miles)				
	Los Angeles	Orange	Riverside	San Bernardino	SCAB
Passenger cars	85.6	24.1	6.0	10.2	125.9
Light-duty trucks (<6000 lbs)	14.8	4.2	1.0	1.8	21.8
Total	100.4	28.3	7.0	12.0	147.7

LDV VMT to passenger cars and trucks was obtained from CALTRANS. Tables 7 to 9 present the disaggregating factors for each road type and grid type. As stated in Section 3, these factors were derived from traffic count data obtained for the SCAB.

Table 7. Season and Weekday/Weekend Disaggregating Factors

	NON - FREEWAY GRID SQUARE TYPE					FREEWAY GRID SQUARE TYPE				
	1	2	3	4	5	1	2	3	4	5
SEASON FACTORS										
WINTER	.9740	.9740	.9740	1.0180	1.0180	.9500	.9752	.8888	.9452	.8368
SPRING	.9960	.9960	.9960	1.0860	1.0860	1.0076	1.0296	1.0360	1.0340	1.0128
SUMMER	1.0264	1.0264	1.0264	.9160	.9160	1.0428	1.0488	1.0636	1.0428	1.1988
FALL	1.0036	1.0036	1.0036	.9800	.9800	.9996	.9464	.9916	.9780	.9516
WEEKDAY - WEEKEND FACTORS										
WINTER										
WEEKDAY	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
WEEKEND	.7722	.7722	.7722	.8830	.8830	.8356	.8187	.7341	.9540	1.2040
SPRING										
WEEKDAY	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
WEEKEND	.7765	.7765	.7765	.8512	.8512	.8512	.8378	.7942	.9652	1.2845
SUMMER										
WEEKDAY	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
WEEKEND	.7895	.7895	.7895	.8693	.8693	.8592	.8457	.8086	.9670	1.1410
FALL										
WEEKDAY	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
WEEKEND	.7510	.7510	.7510	.8245	.8245	.8211	.8112	.7447	.9375	1.2565

Table 8. Weekday Hourly Disaggregating Factors

WEEKDAY HOUR	NON - FREEWAY GRID SQUARE TYPE 1	2	3	4	5	FREEWAY GRID SQUARE TYPE 1	2	3	4	5
1	.015	.015	.015	.006	.006	.016	.014	.013	.011	.014
2	.008	.008	.008	.004	.004	.008	.008	.007	.007	.012
3	.005	.005	.005	.003	.003	.005	.005	.005	.006	.010
4	.004	.004	.004	.003	.003	.004	.004	.005	.005	.010
5	.005	.005	.005	.006	.006	.005	.005	.006	.007	.013
6	.014	.014	.014	.020	.020	.015	.013	.016	.013	.021
7	.052	.052	.052	.043	.043	.057	.049	.057	.034	.036
8	.070	.070	.070	.051	.051	.075	.069	.084	.071	.047
9	.063	.063	.063	.050	.050	.066	.064	.066	.061	.052
10	.055	.055	.055	.053	.053	.053	.058	.048	.053	.059
11	.052	.052	.052	.062	.062	.050	.055	.046	.054	.063
12	.054	.054	.054	.069	.069	.051	.056	.048	.057	.062
13	.054	.054	.054	.071	.071	.051	.056	.048	.059	.059
14	.056	.056	.056	.069	.069	.052	.057	.049	.058	.060
15	.062	.062	.062	.074	.074	.059	.063	.054	.063	.062
16	.072	.072	.072	.082	.082	.072	.069	.074	.072	.068
17	.073	.073	.073	.080	.080	.072	.067	.086	.075	.073
18	.070	.070	.070	.068	.068	.070	.065	.084	.077	.067
19	.058	.058	.058	.053	.053	.059	.057	.059	.057	.054
20	.043	.043	.043	.043	.043	.044	.046	.041	.044	.043
21	.033	.033	.033	.035	.035	.033	.034	.031	.036	.036
22	.031	.031	.031	.026	.026	.030	.031	.029	.034	.032
23	.029	.029	.029	.018	.018	.029	.030	.024	.025	.026
24	.024	.024	.024	.011	.011	.024	.025	.020	.019	.020

Table 9. Weekend Hourly Disaggregating Factors

WEEKEND HOUR	NON - FREEWAY GRID SQUARE TYPE 1	2	3	4	5	FREEWAY GRID SQUARE TYPE 1	2	3	4	5
1	.031	.031	.031	.014	.014	.029	.031	.027	.019	.016
2	.021	.021	.021	.009	.009	.019	.021	.018	.013	.012
3	.017	.017	.017	.005	.005	.015	.016	.013	.010	.009
4	.009	.009	.009	.003	.003	.008	.008	.008	.007	.008
5	.007	.007	.007	.005	.005	.006	.006	.006	.006	.008
6	.009	.009	.009	.010	.010	.009	.009	.010	.009	.012
7	.018	.018	.018	.020	.020	.019	.018	.020	.018	.020
8	.026	.026	.026	.031	.031	.027	.027	.028	.030	.028
9	.035	.035	.035	.044	.044	.036	.036	.037	.039	.041
10	.044	.044	.044	.059	.059	.046	.045	.048	.053	.053
11	.052	.052	.052	.072	.072	.055	.054	.056	.061	.063
12	.060	.060	.060	.079	.079	.062	.062	.066	.066	.066
13	.066	.066	.066	.080	.080	.065	.067	.066	.068	.065
14	.066	.066	.066	.077	.077	.064	.066	.066	.068	.065
15	.064	.064	.064	.076	.076	.063	.064	.067	.070	.070
16	.067	.067	.067	.076	.076	.066	.066	.069	.073	.075
17	.066	.066	.066	.072	.072	.065	.066	.070	.074	.078
18	.064	.064	.064	.065	.065	.065	.065	.068	.072	.075
19	.063	.063	.063	.056	.056	.065	.062	.061	.062	.064
20	.056	.056	.056	.046	.046	.057	.056	.053	.052	.052
21	.045	.045	.045	.036	.036	.046	.045	.045	.042	.041
22	.040	.040	.040	.028	.028	.040	.039	.037	.035	.033
23	.039	.039	.039	.021	.021	.033	.038	.032	.029	.026
24	.035	.035	.035	.018	.018	.034	.035	.027	.023	.019

Vehicle Population and Average Mileage Estimates

Based on vehicle registration data for California, estimates of model year population distributions for passenger cars and light duty trucks were obtained for each of the four seasons studied. Total statewide California registration data were used to derive the quarterly population distribution and these data were applied to the SCAB. Tables 10 and 11 contain the basic registration data from the indicated sources and scrappage rates that were used to derive the VMT model year distribution as discussed in the previous section. The resultant VMT distributions for passenger cars and light duty trucks are presented in Tables 12 and 13.

Emission Factors

Tables 14 and 15 present the FTP emission factors for California vehicles in 1975. These data are derived in (8) and differ from thosee data recommended in (3). This difference results from the use in (11) of an implied constant deterioration factor applied to data derived from a 1972 emission test program. The data in (3) was derived from a number of sources and other considerations (including the 1972 program) and thus cannot be derived directly from the 1972 data with a constant deterioration factor.

Emission factors for particulates and SO_x are included in Tables 14 and 15 and represent average, rather than composite factors.

Evaporative emission factors are also included in Tables 14 and 15. These emission factors are used in the manner described in Section 3. The general population distribution referred to in the methodology is illustrated in Figure 14. As suggested by CALTRANS, 4.7 trips per day were assumed for all LDVs in the SCAB.

Temperature

Table 16 presents the temperatures used for the emission factor generation. A sinusoidal curve was fit to this data.

Table 10. California Registration Data

Source	Autos	LDT
(1) December 31, 1974	11,061,877	1,837,754
(1) December 31, 1975	11,119,563	1,937,447
(1) New registrations during 1975	807,983	146,847
Total scrapped during 1975	750,297	47,154
Total annual scrappage rate	6.78%	2.6%
(2) New car sales		
April to June	170,848	38,056
July to September	191,756	47,571
October to December	180,267	36,863

(1) Department of Motor Vehicles

(2) Reuben Donnelley Co.

Table 11. Scrappage Rates(%)

Years Old	Annual Scrappage Rate	
	Passenger Cars	LD Trucks
0	0	0
1	0	0
2	.565	0.216
3	1.113	0.432
4	1.695	0.648
5	2.26	0.864
6	2.825	1.08
7	3.39	1.29
8	3.955	1.512
9	4.52	1.728
10	5.085	1.944
11	5.65	2.16
12	6.215	2.376
13	6.78	2.592
14	7.345	2.808
15	7.91	3.024
16	8.475	3.24
17	9.04	3.456
18	9.605	3.672
19	10.17	3.888
20	10.735	4.104
21	11.3	4.32
22	11.865	4.536
23	12.43	4.752
24	12.995	4.968
25	13.56	5.184

Table 12. VMT Model Year Distribution for Light Duty Passenger Cars

MODEL YEAR	ANNUAL MILEAGE	WINTER POP DIS	WINTER VMT DIS	SPRING POP DIS	SPRING VMT DIS	SUMMER POP DIS	SUMMER VMT DIS	FALL POP DIS	FALL VMT DIS
1977	16350	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0179	.0374
1976	15190	.0205	.0425	.0377	.0763	.0565	.1120	.0560	.1084
1975	13650	.0922	.1716	.0913	.1664	.0903	.1607	.0893	.1554
1974	12000	.1040	.1702	.1029	.1647	.1015	.1589	.1003	.1534
1973	10450	.0984	.1401	.0972	.1355	.0957	.1305	.0945	.1258
1972	9060	.0848	.1047	.0836	.1010	.0823	.0972	.0810	.0936
1971	7770	.0811	.0859	.0798	.0828	.0785	.0795	.0772	.0764
1970	6610	.0864	.0778	.0849	.0749	.0833	.0719	.0819	.0690
1969	5570	.0748	.0568	.0734	.0546	.0719	.0523	.0706	.0501
1968	4650	.0629	.0399	.0616	.0382	.0603	.0366	.0591	.0350
1967	3860	.0615	.0323	.0602	.0310	.0588	.0296	.0575	.0283
1966	3189	.0602	.0262	.0589	.0251	.0575	.0239	.0561	.0228
1965	2640	.0438	.0158	.0428	.0151	.0417	.0144	.0407	.0137
1964	2220	.0313	.0095	.0306	.0091	.0298	.0086	.0290	.0082
1963	2000	.0233	.0063	.0227	.0060	.0220	.0057	.0214	.0055
1962	2000	.0146	.0040	.0142	.0038	.0138	.0036	.0134	.0034
1961	2000	.0130	.0035	.0126	.0034	.0122	.0032	.0119	.0030
1960	2000	.0473	.0129	.0456	.0122	.0438	.0114	.0422	.0108

Table 13. VMT Model Year Distribution for Light Duty Trucks

MODEL YEAR	ANNUAL MILEAGE	WINTER POP DIS	WINTER VMT DIS	SPRING POP DIS	SPRING VMT DIS	SUMMER POP DIS	SUMMER VMT DIS	FALL POP DIS	FALL VMT DIS
1977	16350	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0187	.0395
1976	15190	.0194	.0410	.0391	.0807	.0628	.1260	.0619	.1213
1975	13650	.1036	.1966	.1018	.1887	.0997	.1798	.0981	.1729
1974	12000	.1240	.2070	.1220	.1987	.1193	.1892	.1174	.1819
1973	10450	.1065	.1548	.1047	.1485	.1024	.1413	.1007	.1358
1972	9060	.0740	.0933	.0727	.0894	.0711	.0851	.0699	.0817
1971	7770	.0437	.0472	.0429	.0452	.0419	.0430	.0412	.0413
1970	6610	.0708	.0651	.0695	.0624	.0679	.0593	.0667	.0569
1969	5570	.0525	.0407	.0515	.0389	.0502	.0370	.0493	.0355
1968	4550	.0442	.0286	.0433	.0273	.0422	.0259	.0414	.0249
1967	3860	.0467	.0250	.0457	.0240	.0446	.0227	.0437	.0218
1966	3189	.0496	.0220	.0486	.0210	.0473	.0199	.0463	.0191
1965	2640	.0456	.0167	.0446	.0160	.0434	.0151	.0425	.0145
1964	2220	.0360	.0111	.0353	.0106	.0343	.0101	.0336	.0096
1963	2000	.0282	.0078	.0275	.0075	.0268	.0071	.0262	.0068
1962	2000	.0197	.0055	.0192	.0052	.0187	.0049	.0182	.0047
1961	2000	.0221	.0061	.0216	.0059	.0210	.0055	.0205	.0053
1960	2000	.1134	.0315	.1101	.0299	.1065	.0281	.1036	.0267

Table 14. 1975 Emission Factors for Light Duty Passenger Cars

Model Year	NOX	Hydrocarbons				CO	SOX	Particulates
		Exhaust	Crankcase	Evaporative				
				Diurnal	Hot Soak			
1976	2.00 gm/mi	.6 gm/mi	0.0 gm/mi	1.5 gm/day	5.3 gm/trip	5.40 gm/mi	.13 gm/mi	.25 gm/mi
1975	2.00	.6		1.5	5.3	5.40		.25
1974	2.31	3.12		1.5	5.3	35.38		.54
1973	3.47	4.62		1.5	5.3	43.34		
1972	3.81	4.63		1.5	5.3	53.70		
1971	3.83	5.07		4.2	5.3	68.23		
1970	4.46	8.30		4.2	9.9	89.20		
1969	5.00	6.10		14.1		72.58		
1968	4.44	8.06				71.66		
1967	3.77	6.43				84.45		
1966	3.43	8.85				96.93		
1965	3.34	8.67				93.50		
1964	3.34	8.67				93.50		
1963			.80					
1962			.80					
1961			.80					
1960			4.10					
Pre-1960			4.10					

Table 15. 1975 Emission Factors for Light Duty Trucks

Model Year	NOX	Hydrocarbons				CO	SOX	Particulates
		Exhaust	Crankcase	Evaporative				
				Diurnal	Hot Soak			
1976	2.00 gm/mi	.6 gm/mi	0.0 gm/mi	1.5 gm/day	5.3 gm/trip	10.20 gm/mi	.13 gm/mi	.25 gm/mi
1975	2.00	2.0		1.5	5.3	12.00		.25
1974	2.31	3.12		1.5	5.3	35.38		.54
1973	3.47	4.62		1.5	5.3	43.34		
1972	3.81	4.63		1.5	5.3	53.70		
1971	3.83	5.07		4.2	5.3	68.23		
1970	4.46	8.30		4.2	9.9	89.20		
1969	5.00	6.10		14.1		72.58		
1968	4.44	8.06				71.66		
1967	3.77	6.43				84.45		
1966	3.43	8.85				96.93		
1965	3.34	8.67				93.50		
1964	3.34	8.67				93.50		
1963			.80					
1962			.80					
1961			.80					
1960			4.10					
Pre-1960			4.10					

Table 16. Seasonal Temperature Variations

Season	Average	High	Low
Winter	54°F	64°F	45°F
Spring	59°F	67°F	52°F
Summer	69°F	76°F	62°F
Fall	65°F	73°F	57°F

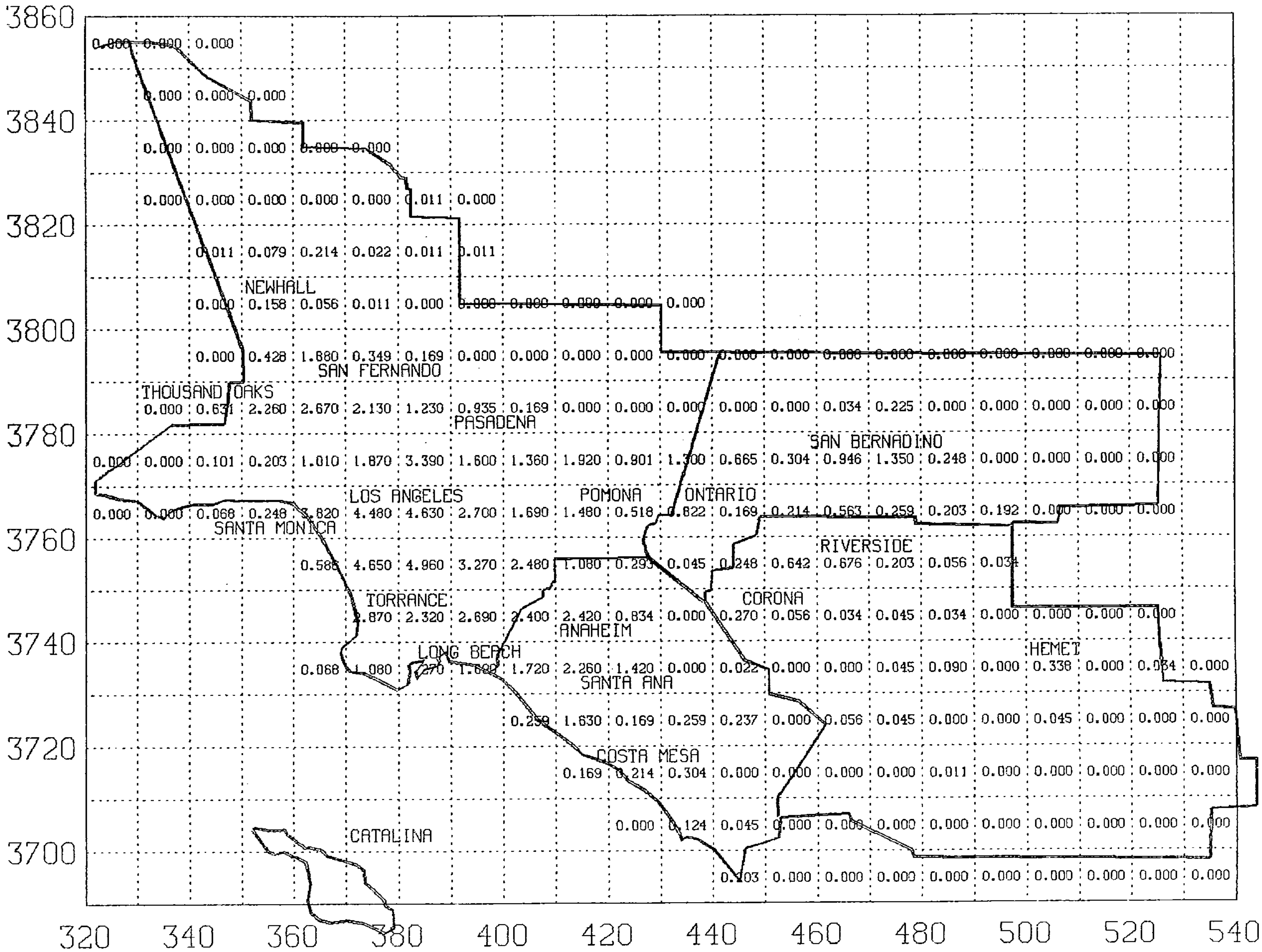


Figure 14. General Population Distribution (Percent of Total)

The resultant temperature correction factors for exhaust hydrocarbons, carbon monoxide, and nitrogen oxides are shown in Figures 15 through 17 for non-catalyst and catalyst vehicles.

The behavior of these three emissions with temperature serves to explain their somewhat contradictory seasonal trends. Since VMT is in general greatest in the summer, it would be expected that emissions would be greatest in the summer. For exhaust hydrocarbons, carbon monoxide and nitrogen oxides, this is not the case as is shown in the following inventory. This results from the fact that the decrease in temperature factor during the summer months more than compensates for the increase in VMT and the emissions are actually less.

Hot/Cold Operation

As stated in the previous section, the FTP emission factor represents 20% cold operation and 80% hot operation. Although correction factors to account for different percentages are available and the hot/cold operation is obviously a function of location and time of day, there has not been sufficient analysis to provide a detailed description of this factor in the SCAB. Therefore, it is assumed that a correction factor of unity (i.e., 20% cold and 80% hot operation) applies to the SCAB uniformly.

Speed Correction Factors

Figures 18 through 53 present the data supplied from the Olson chase car program. The data represent emissions estimates for hot-operation emissions in calendar year 1972 for each of the driving cycles as indicated by their average speed. As discussed in the previous section, these cycles are not "representative" cycles, but represent a random sample of all possible cycles contained in the speed-mode driving matrices developed from the chase car data. The spread of the data about each average speed for hydrocarbons and carbon monoxide indicates that emissions for any average speed are fairly consistant (i.e., different driving cycles for a particular average speed yield approximately the same emissions). For NO_x,

FIGURE 15.

HYDROCARBONS
TEMPERATURE FACTORS

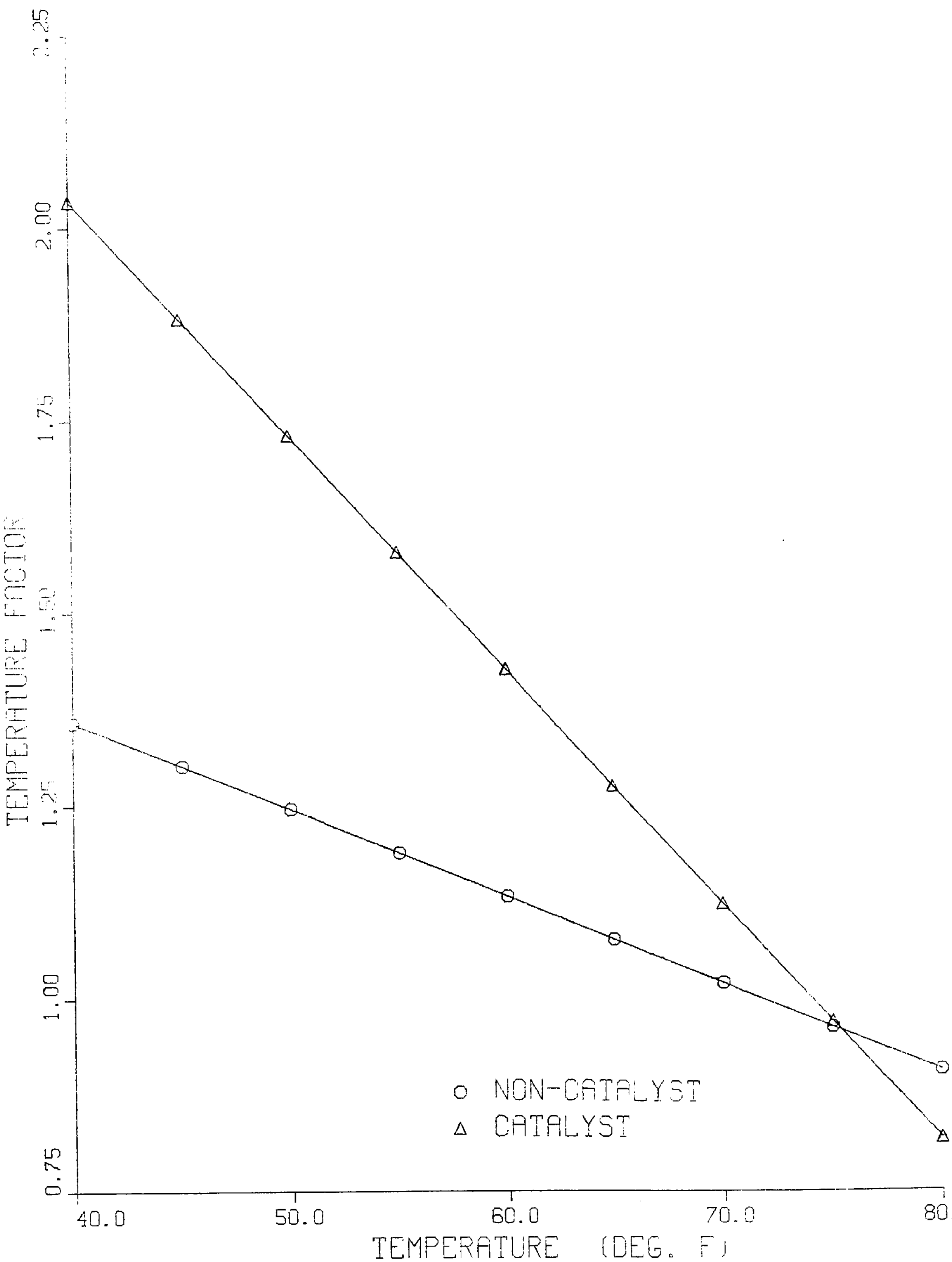
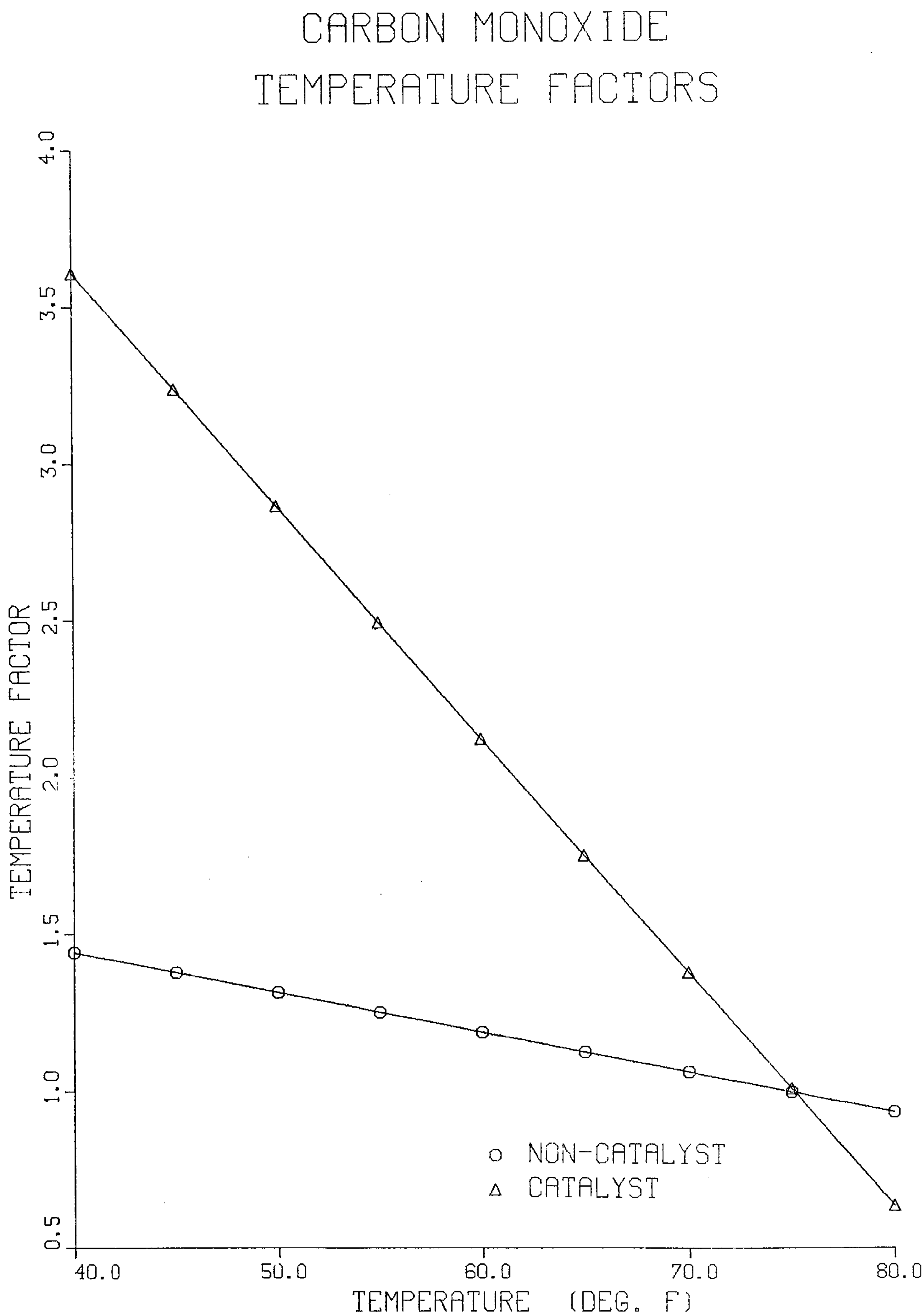


FIGURE 16.



CARBON MONOXIDE
TEMPERATURE FACTORS
TEMPERATURE FACTOR
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
40.0
50.0
60.0
70.0
80.0
TEMPERATURE (DEG. F)
NON-CATALYST
CATALYST

FIGURE 17.

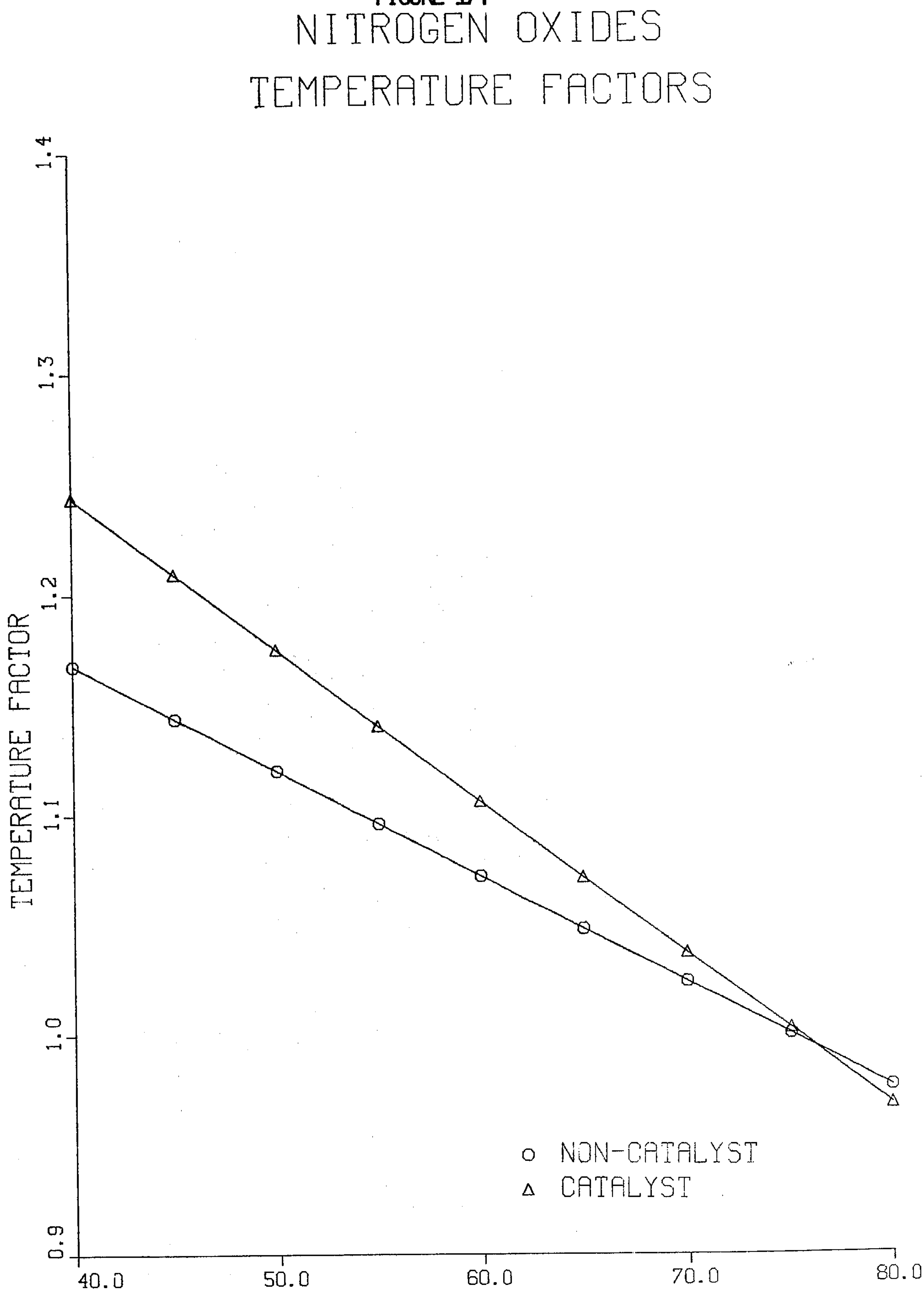

NITROGEN OXIDES
TEMPERATURE FACTORS
TEMPERATURE FACTOR
1.4
1.3
1.2
1.1
1.0
0.9
40.0
50.0
60.0
70.0
80.0
TEMPERATURE (DEG. F)
NON-CATALYST
CATALYST

FIGURE 18. CYCLE EMISSIONS DATA

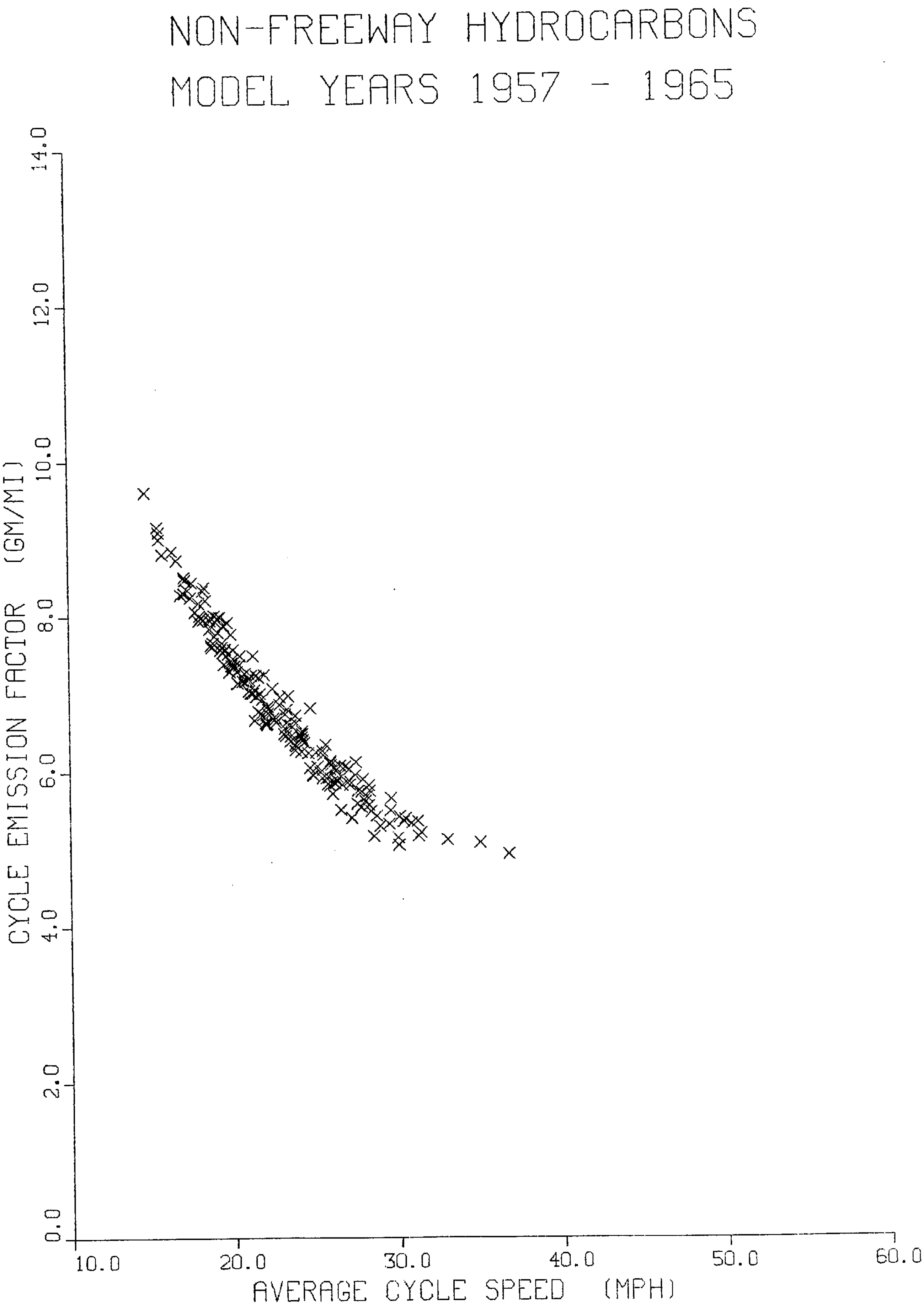


FIGURE 19. CYCLE EMISSIONS DATA

NON-FREEWAY HYDROCARBONS
MODEL YEARS 1966 - 1967

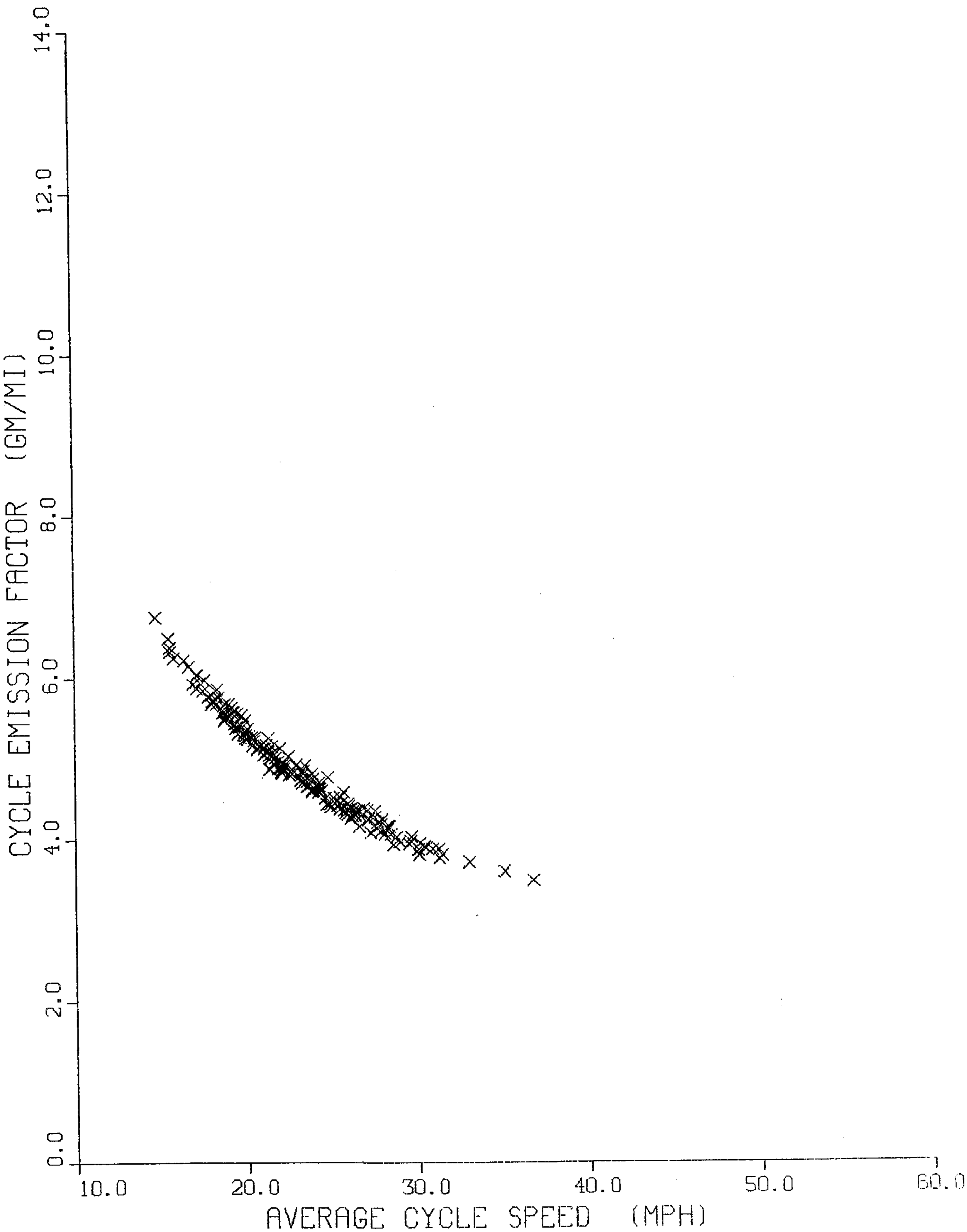


FIGURE 20. CYCLE EMISSIONS DATA

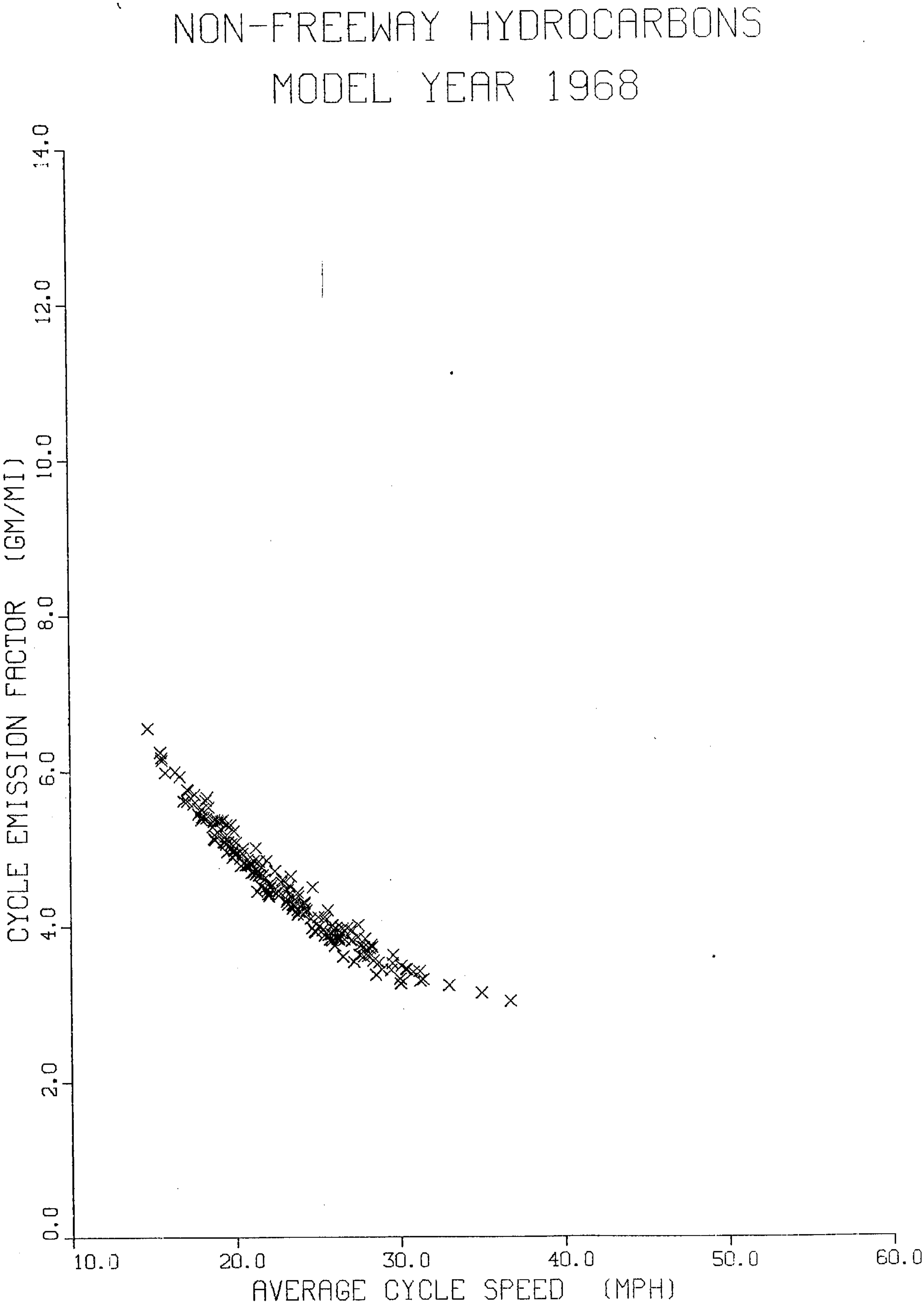


FIGURE 21. CYCLE EMISSIONS DATA

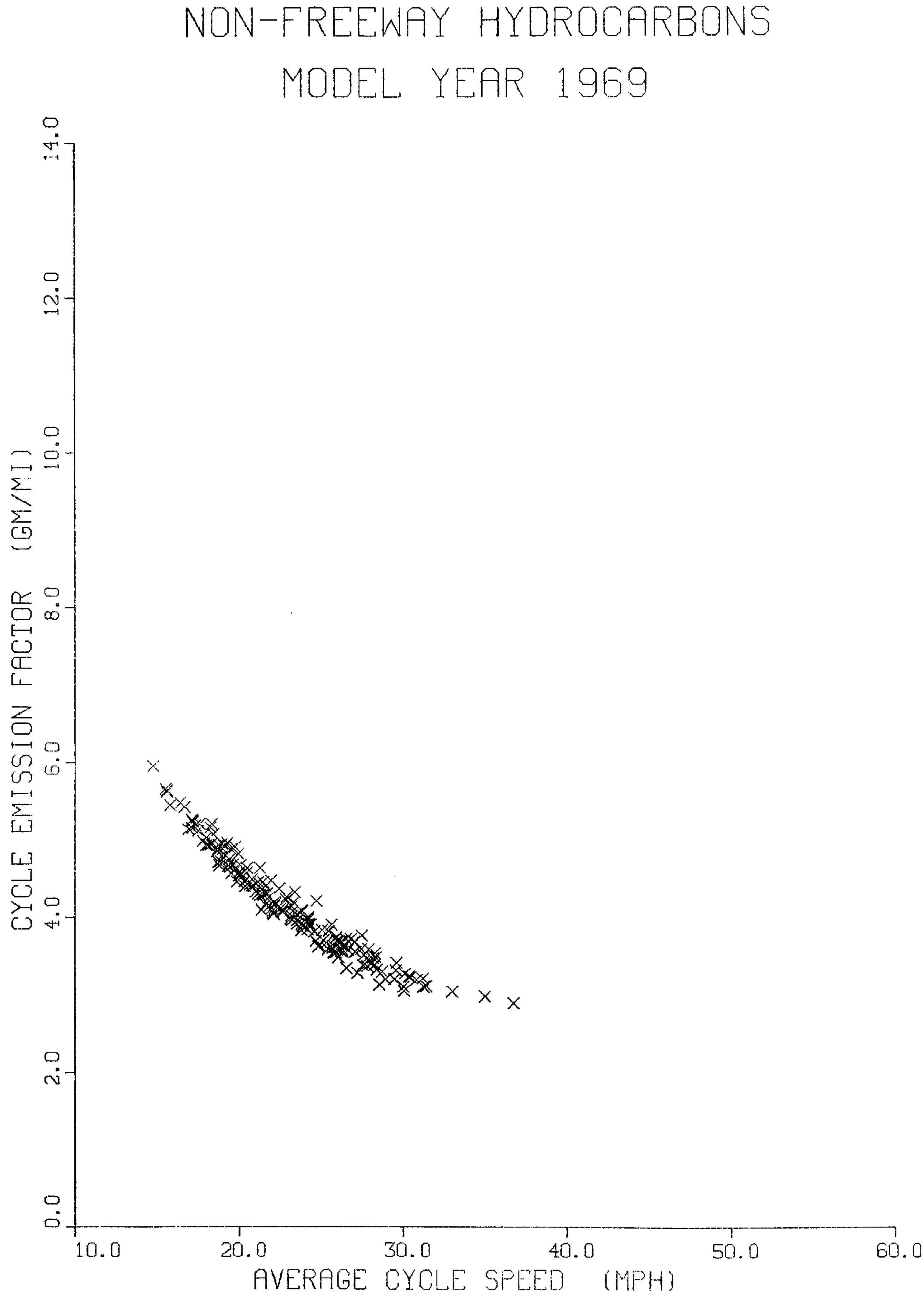


FIGURE 22. CYCLE EMISSIONS DATA

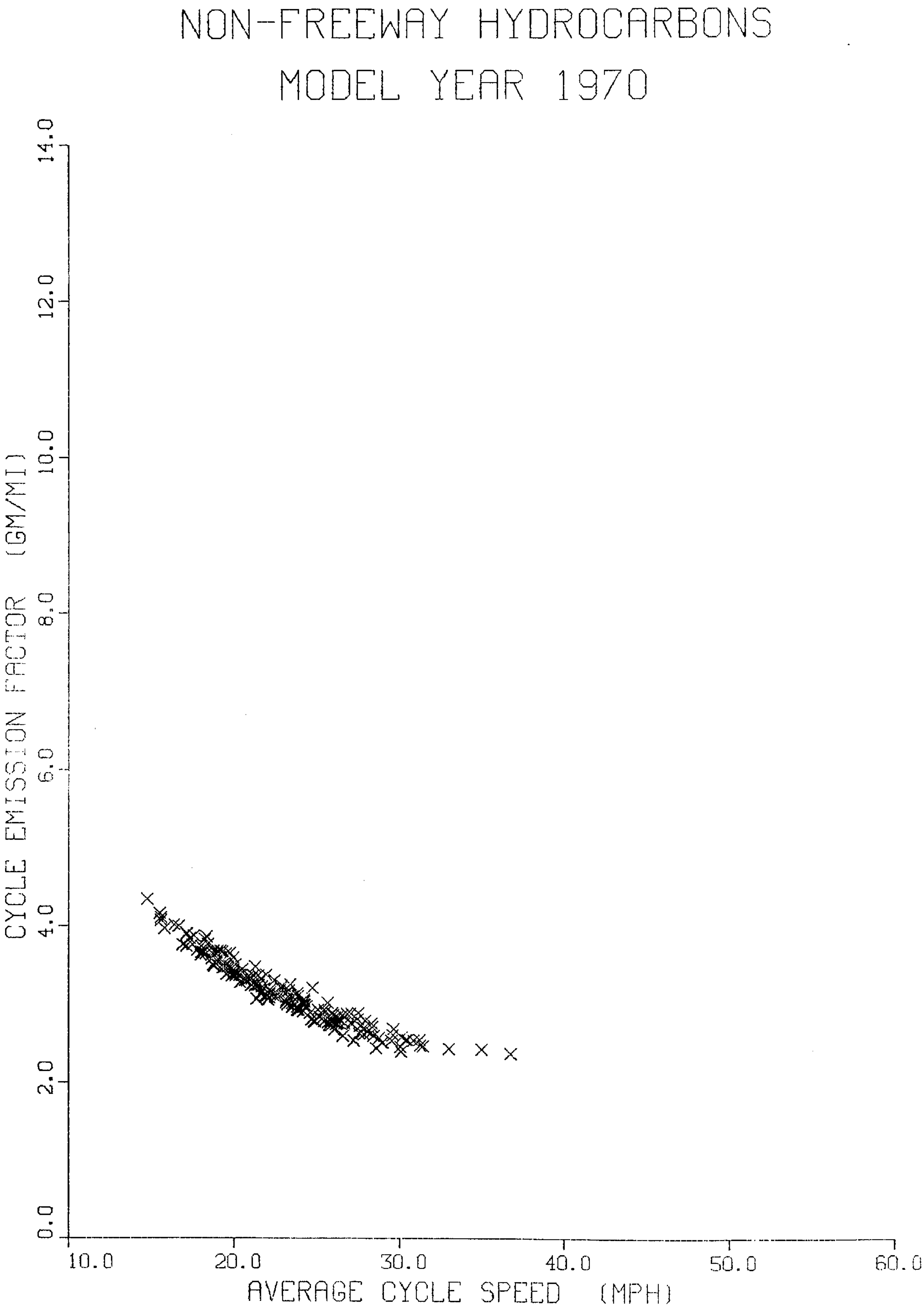


FIGURE 23. CYCLE EMISSIONS DATA

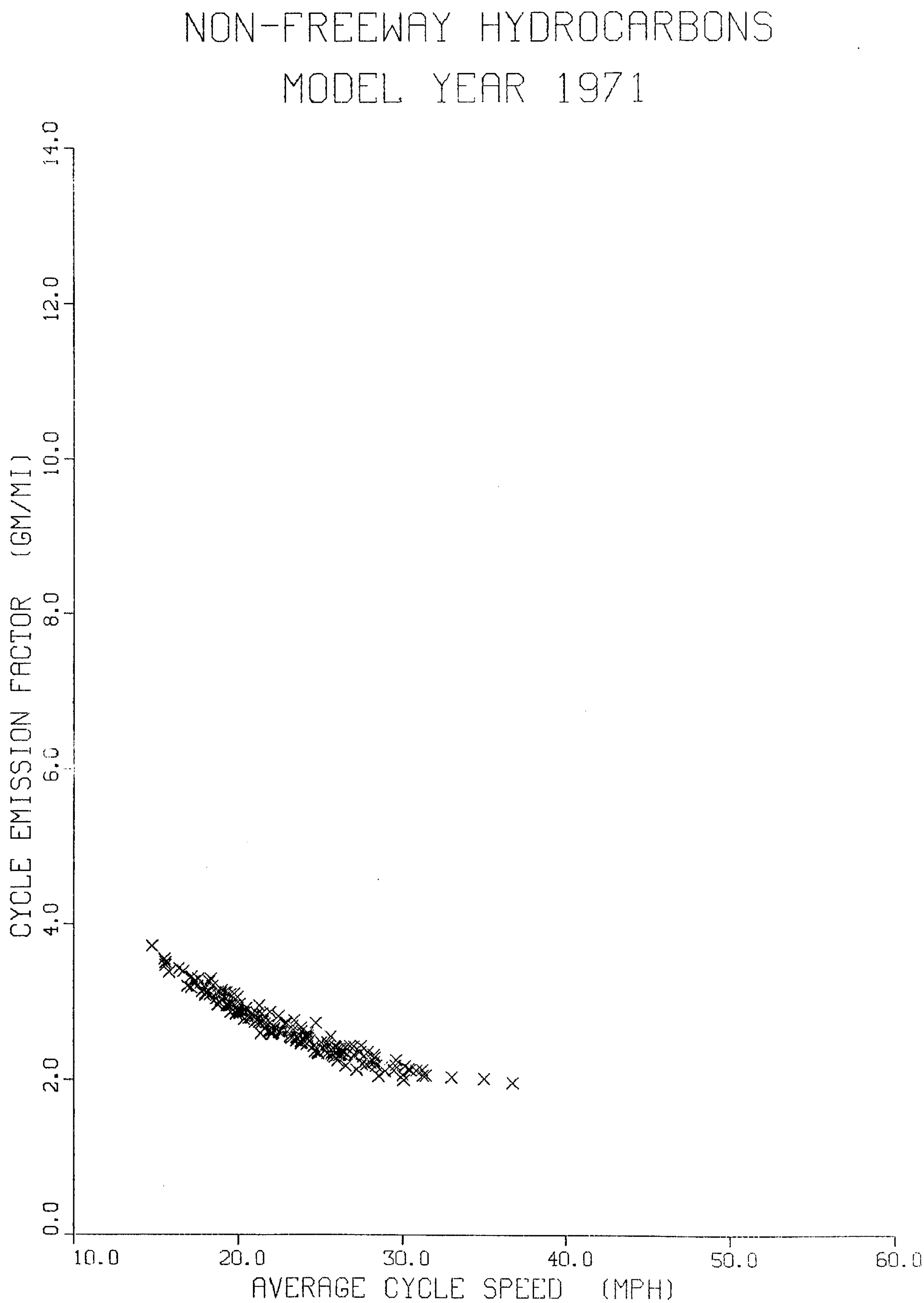


FIGURE 24. CYCLE EMISSIONS DATA

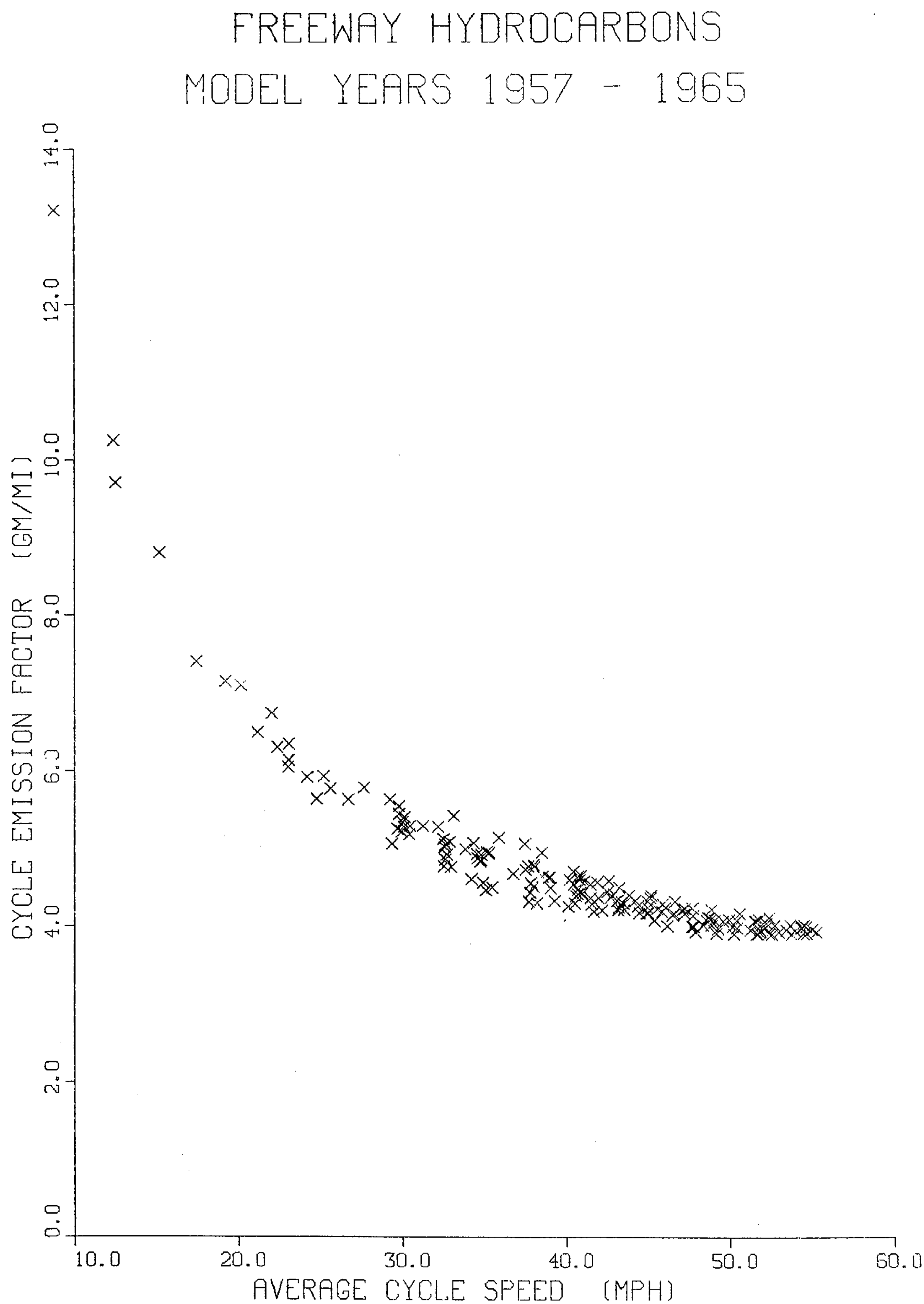


FIGURE 25. CYCLE EMISSIONS DATA

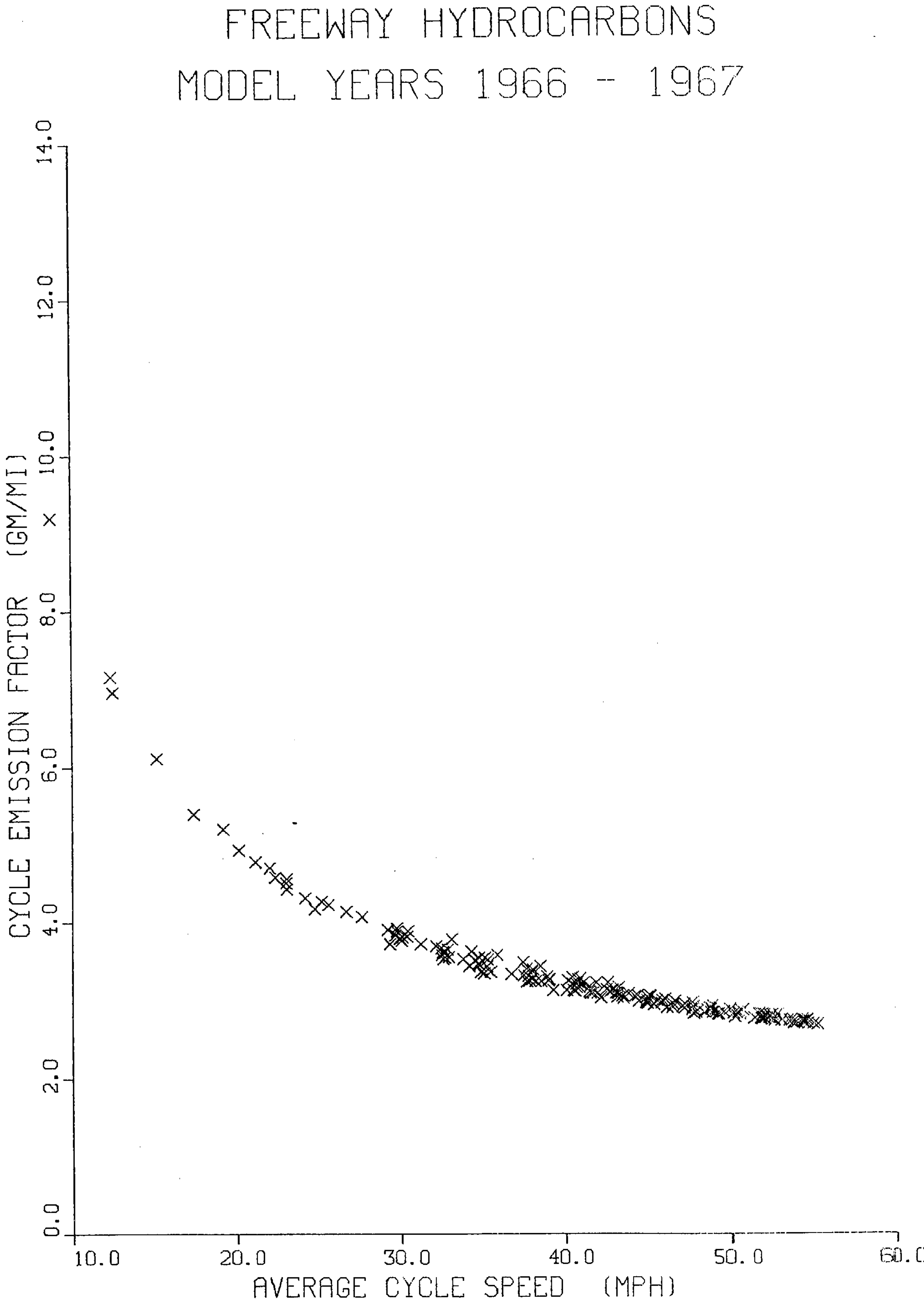


FIGURE 26. CYCLE EMISSIONS DATA

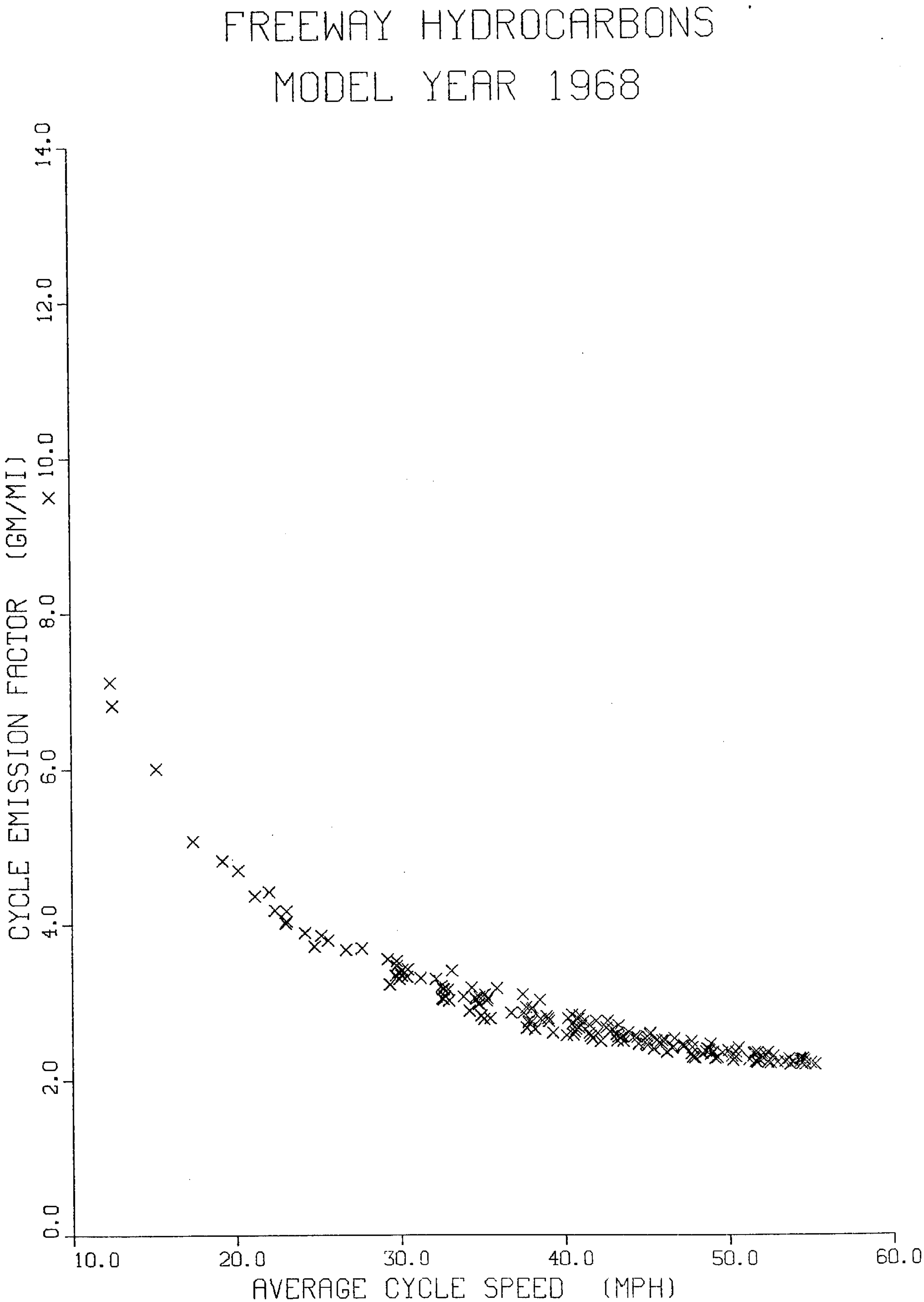


FIGURE 27. CYCLE EMISSIONS DATA

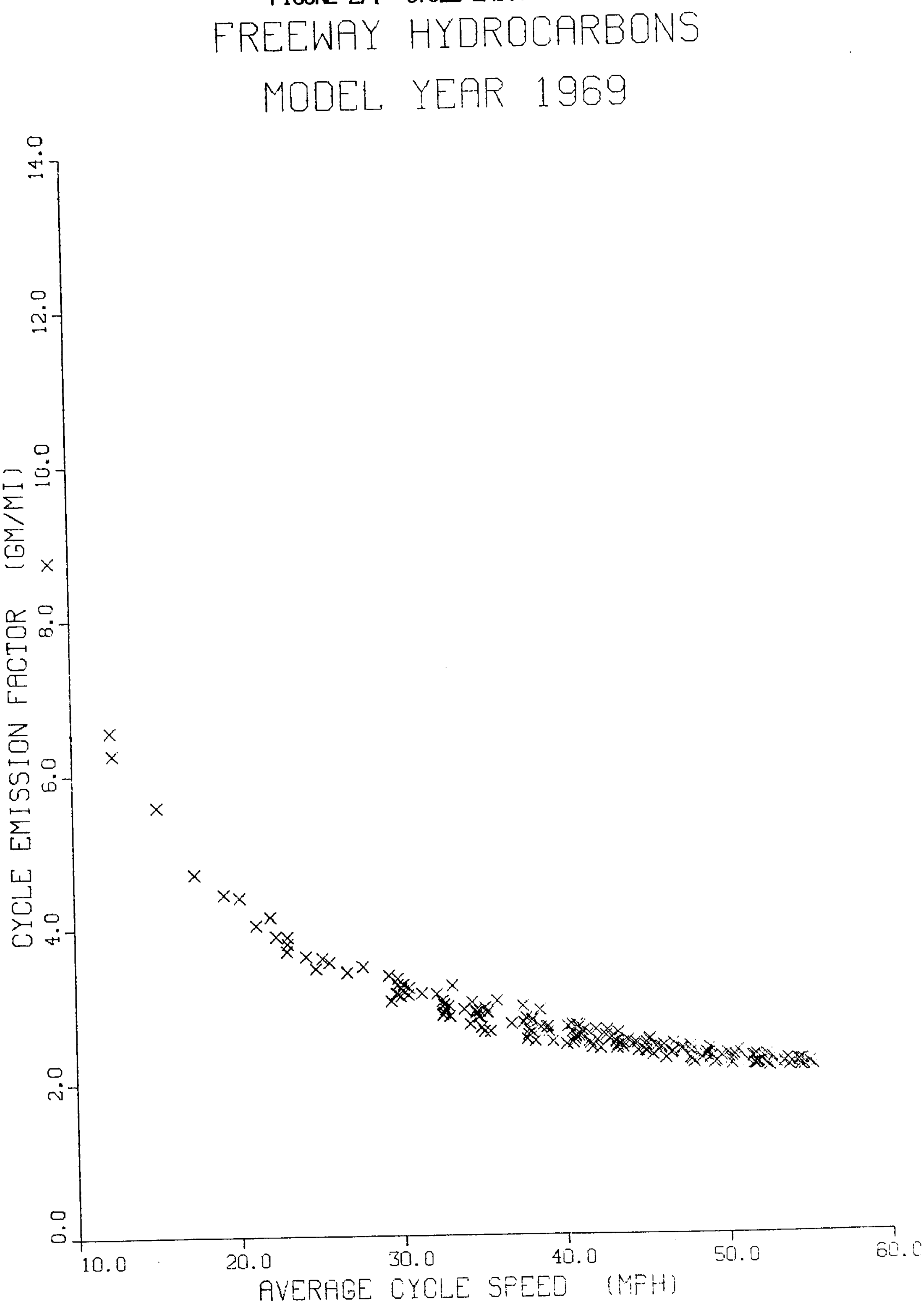


FIGURE 28. CYCLE EMISSIONS DATA

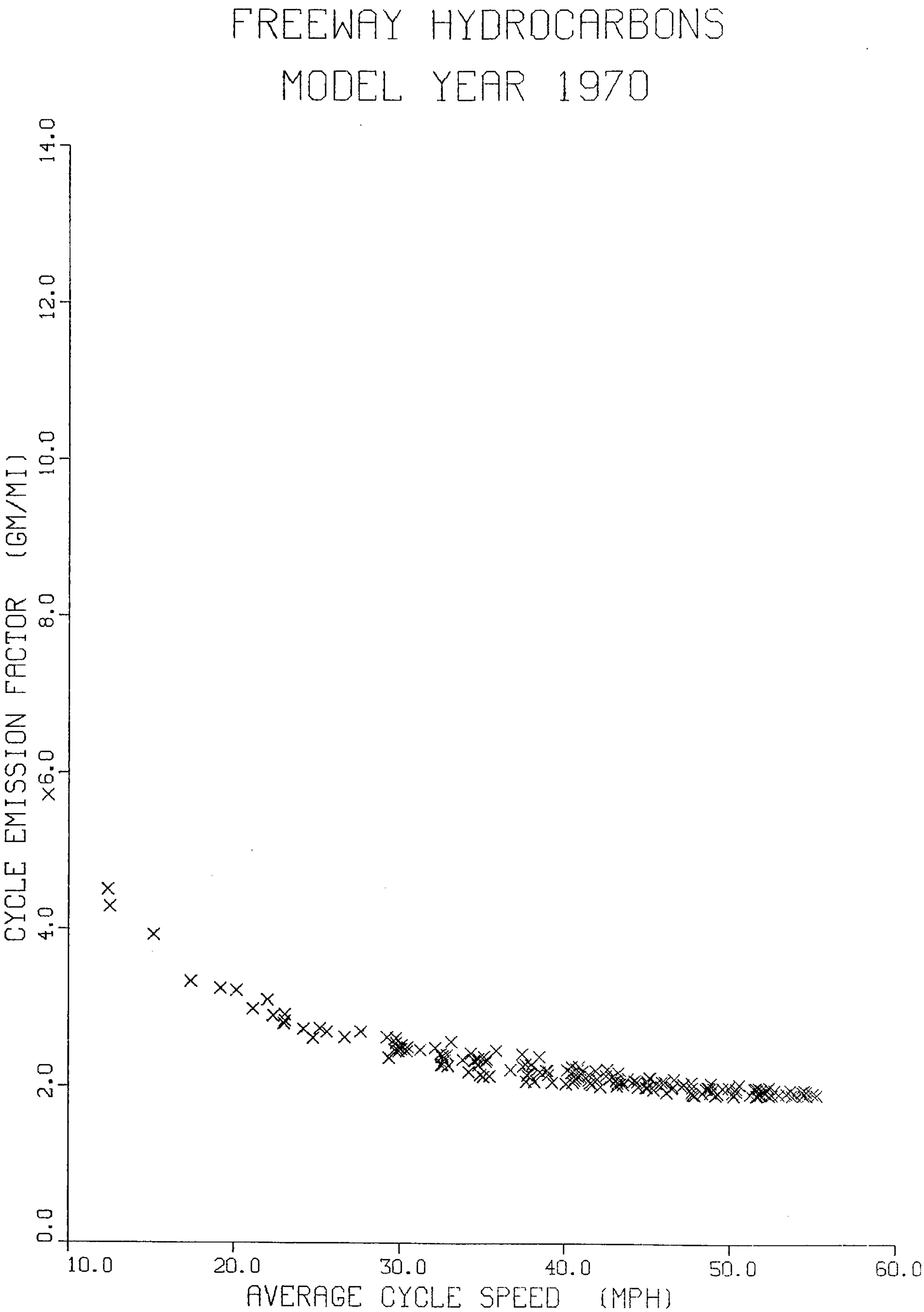


FIGURE 29. CYCLE EMISSIONS DATA

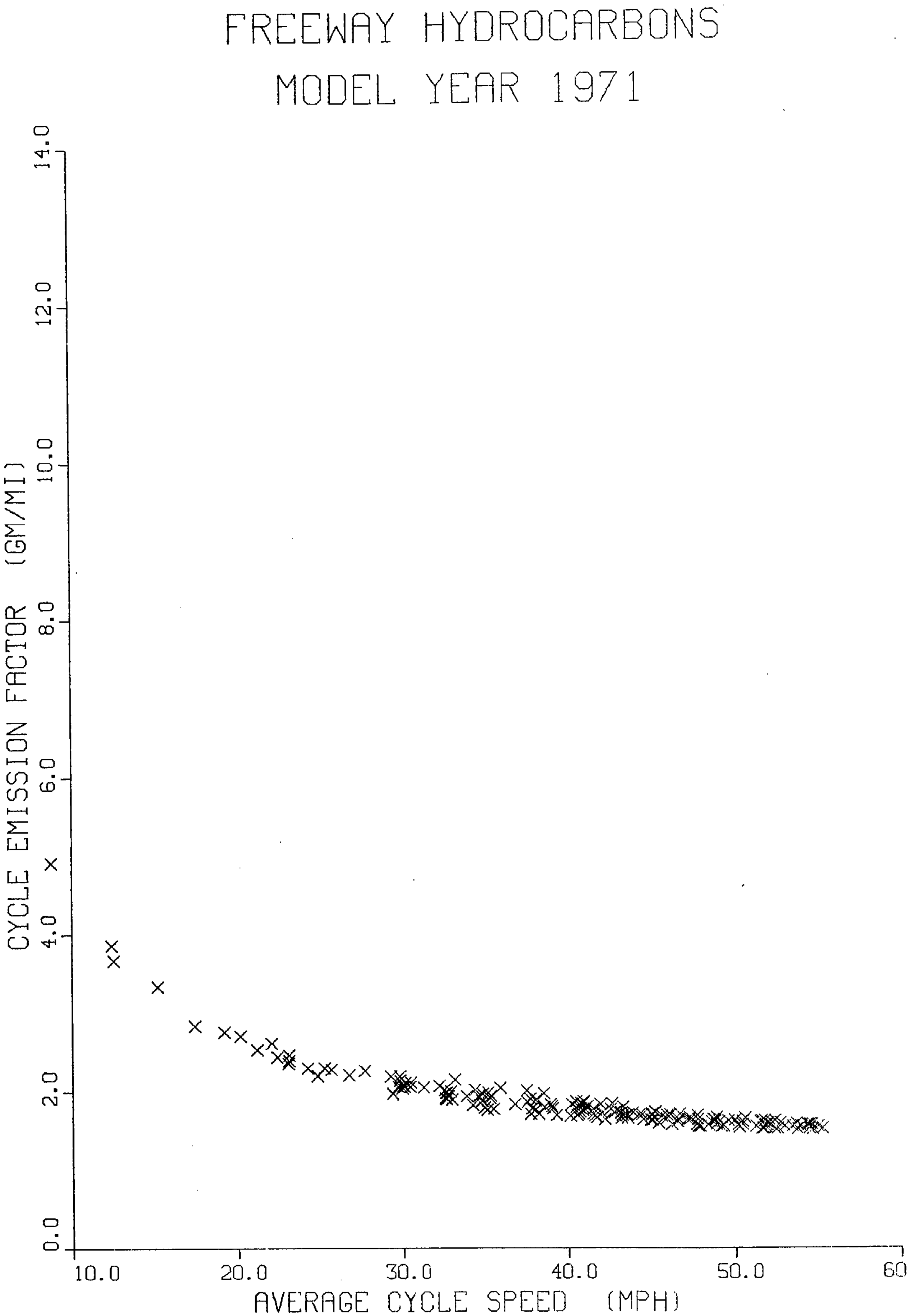


FIGURE 30. CYCLE EMISSIONS DATA

NON-FREEWAY CARBON MONOXIDE

MODEL YEARS 1957 - 1965

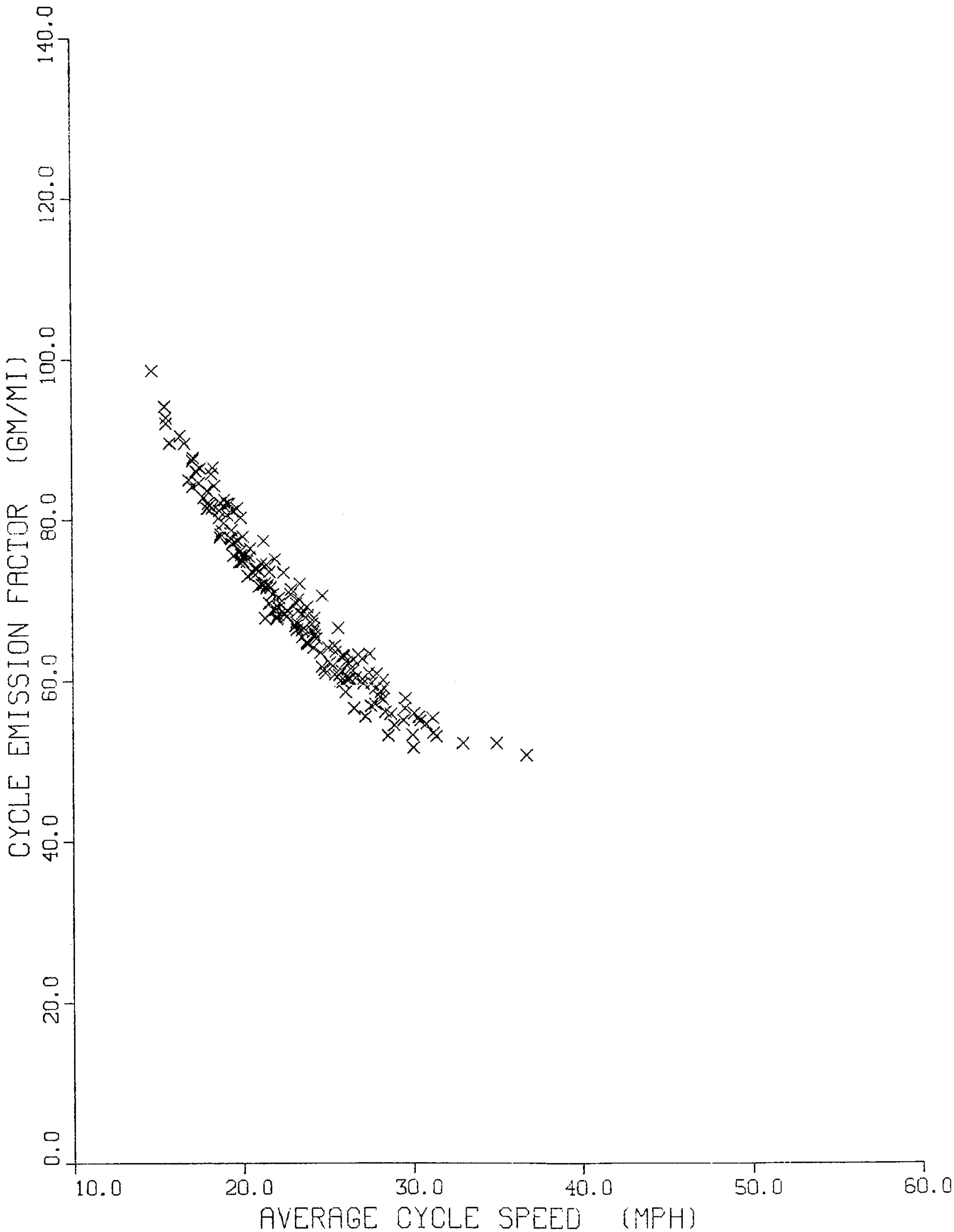


FIGURE 31. CYCLE EMISSIONS DATA

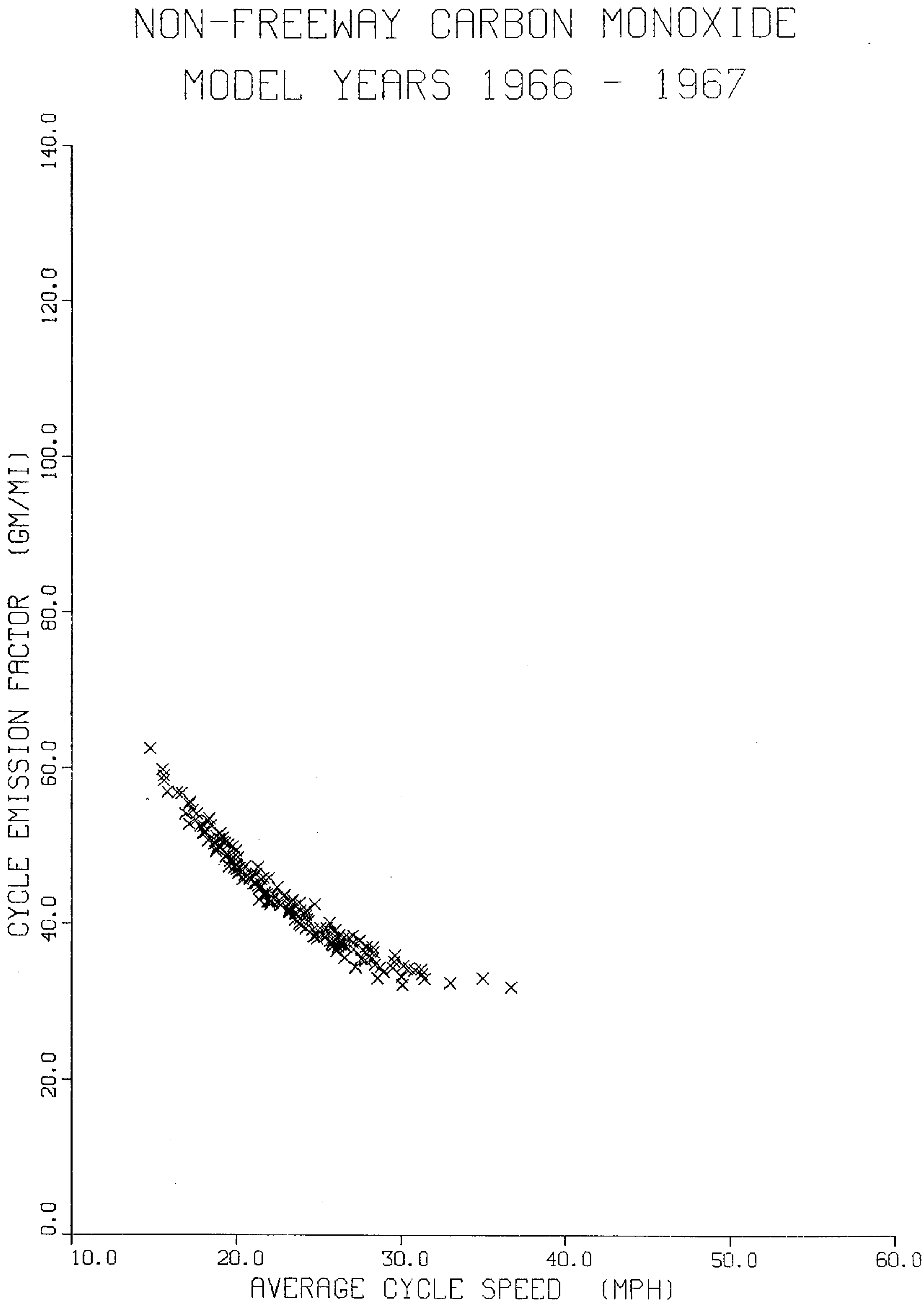


FIGURE 32. CYCLE EMISSIONS DATA

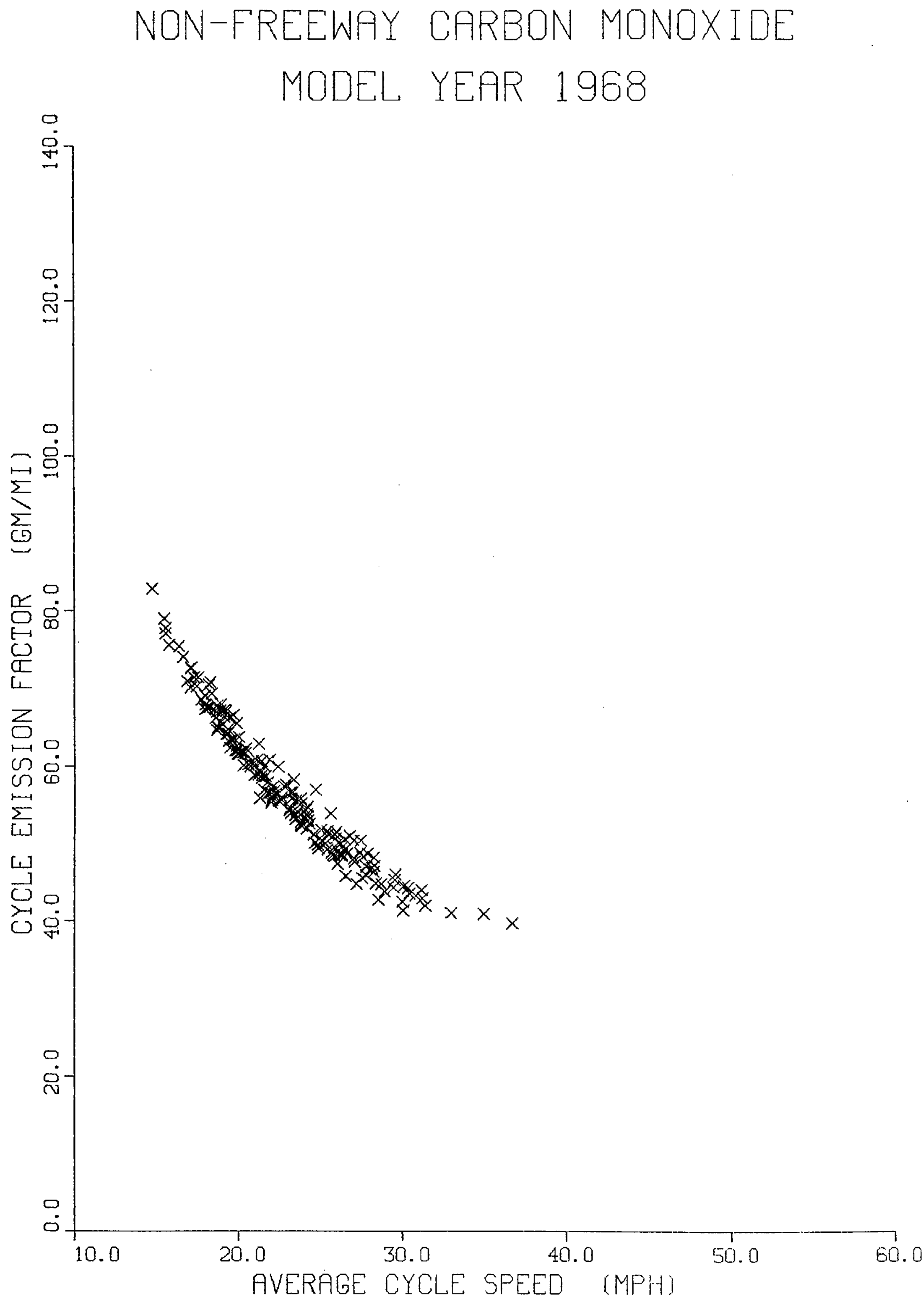


FIGURE 33. CYCLE EMISSIONS DATA

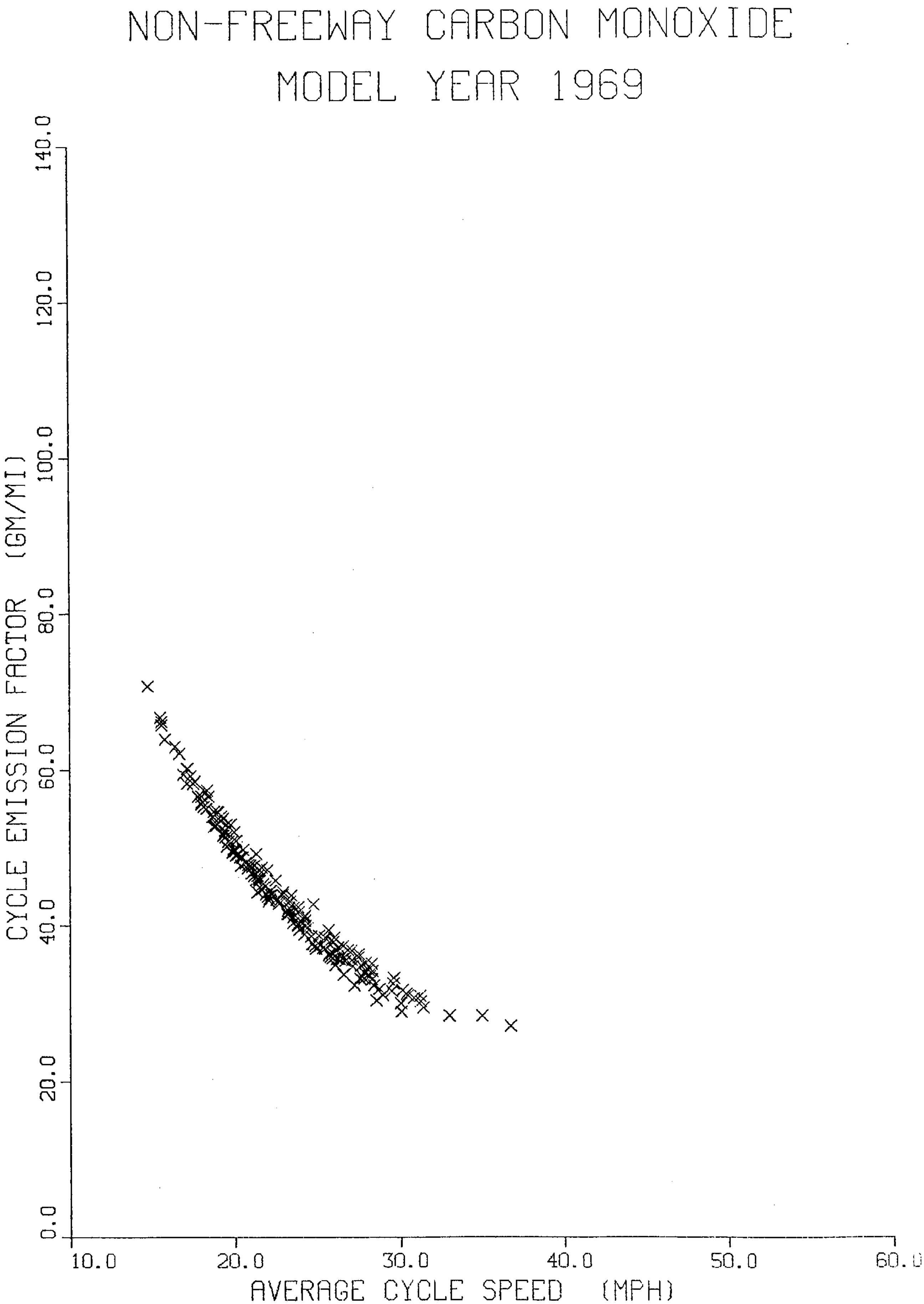


FIGURE 34. CYCLE EMISSIONS DATA